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AIR POLLUTANTS OVER THE CALIFORNIA DESERT

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A PRELIMINARY STUDY OF THE

AIR POLLUTANTS OVER THE CALIFORNIA DESERT

FINAL REPORT SUBMITTED TO THE
BUREAU OF LAND MANAGEMENT,
RIVERSIDE DISTRICT OFFICE

BY

GLOBAL WEATHER CONSULTANTS, INC.
12 S. FIRST ST., SUITE 701
SAN JOSE, CALIFORNIA 95113

DECEMBER 1977

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AIR POLLUTANTS OVER THE CALIFORNIA DESERT

Final Report Submitted to the

BUREAU OF LAND MANAGEMENT,

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GLOBAL WEATHER CONSULTANTS, INC.

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Prepared by

Albert Miller and Peter Lester

December 1977

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Abstract

A preliminary study of the distribution of air pollutants and their transport over the California desert was undertaken. A light aircraft, equipped with meteorological and air pollution sampling instruments, was flown over most of the desert during a single six-day period. The data obtained have been analyzed, supplemented by conventional data from ground stations.

The edge of the smog front was sharply defined at the outset of the observational period (Oct. 14-19, 1977) and its easternmost penetration each day was the periphery of the Los Angeles Basin. During these first three days, the concentrations of ozone and of particulates were generally quite low on the eastern side of the smog front, where easterly flow prevailed. When the large-scale flow changed in the middle of the period, the coastal marine air deepened and the polluted air invaded the desert both from the west and from the south.

Oxidants over the desert far from the source regions may reach there through injection aloft above such mountain ranges as the San Gabriel and San Bernardino Mountains. Elevated laminae of pollutants may be periodically mixed downward to the ground by convection. Thus, the high oxidant readings sometimes observed over Death Valley may be due to the downward flux on the lee sides of the Argus and Panamint Ranges.

Particulate loading over the desert when dust is not being raised by activity on the surface is almost always extremely small. At an altitude greater than 200 ft. above the ground, the concentration is generally less than 20 $\mu g/m^3$.

This preliminary study indicates that there is now a significant transport of gaseous contaminants deep into the desert from surrounding populated areas with appropriate atmospheric flow. However, this preliminary study, carried out during a particular flow pattern, can hardly be considered definitive. In order to determine the total impact, further study should be carried out under a variety of meteorological conditions.

1. Introduction

a. Objectives of Study

The growth of population and industry in Southern California has brought with it increased emissions of pollutants. Most of this growth has occurred along the western, upwind periphery of the California Desert Conservation Area. The pollutants are likely to be transported into the desert so that the air quality, particularly in terms of photochemically-produced oxidants, may have deteriorated over the desert during the past few decades.

Unfortunately, there have been no systematic studies of air pollutant transport and background levels in the desert region. There is no knowledge of what the oxidant level would be if the urbanized strip to the west were not there. The few surface monitoring stations cannot represent the conditions over large areas and are almost useless for determining transport. Aircraft surveys provide the best means for determining the spatial and temporal variations of pollutants.

This study utilized an instrumented aircraft to determine the horizontal, vertical, and diurnal distributions of pollutants and of meteorological parameters over a significant portion of the California desert. The pollutant distributions have been related to meteorological conditions and estimates of the transport have been made. It should be understood that this is a preliminary, exploratory study, since six days of observation during a single month is far from sufficient to describe the effects of

sources within the area, atmospheric transport from adjacent areas, and photochemical transformation, all of which vary greatly with season and even from day to day.

b. Methodology of the Study

This study was meant to yield an estimate of the overall levels of pollutants in the desert and of the principal sources. To achieve these ends, it is necessary to measure the flux into the region as well as the in situ levels. To determine the flux both horizontal and vertical gradients of pollutants and the atmospheric flow must be measured. The gradients of pollutants and the stability of the atmosphere (which determines vertical fluxes) over the entire southeast corner of California were measured with an instrumented aircraft. Horizontal flow patterns were obtained by analyzing conventional meteorological data.

(i) Survey flights

An important aspect of planning for the field measurements was the weather because of the relatively few flights that could be made. It was decided that a period should be chosen that would span a transition from a relatively-weak to a moderate flux of pollutants from the outside into the area. This would then give some measure of the locally-generated levels and the imported amounts.

The aircraft flights were carried out on six days (Oct. 14-19, 1977) following the plans presented in the original proposal and at

the October 6 meeting with BLM in Riverside (see Figure 1), except for modifications due to weather conditions, restricted areas and requests by BLM. (The BLM modifications involved some additional soundings near Crestline and Banning and a low level sampling flight near Plaster City to observe the effects of motorcycle activity on dust levels.) As can be seen from Figure 1, efforts were concentrated in three areas: (A), west-central Mojave to the north and adjacent to the Los Angeles/ San Bernardino basin, where it was anticipated that horizontal gradients of pollutants should be marked; (B) east-central Mojave, northeast of and farther removed from the principal upwind sources, where it was anticipated that the levels and gradients of pollution should be much less; and (C) the lower Colorado, southeast and east of the Los Angeles/ San Diego strip which should, on occasion, experience high fluxes of pollutants.

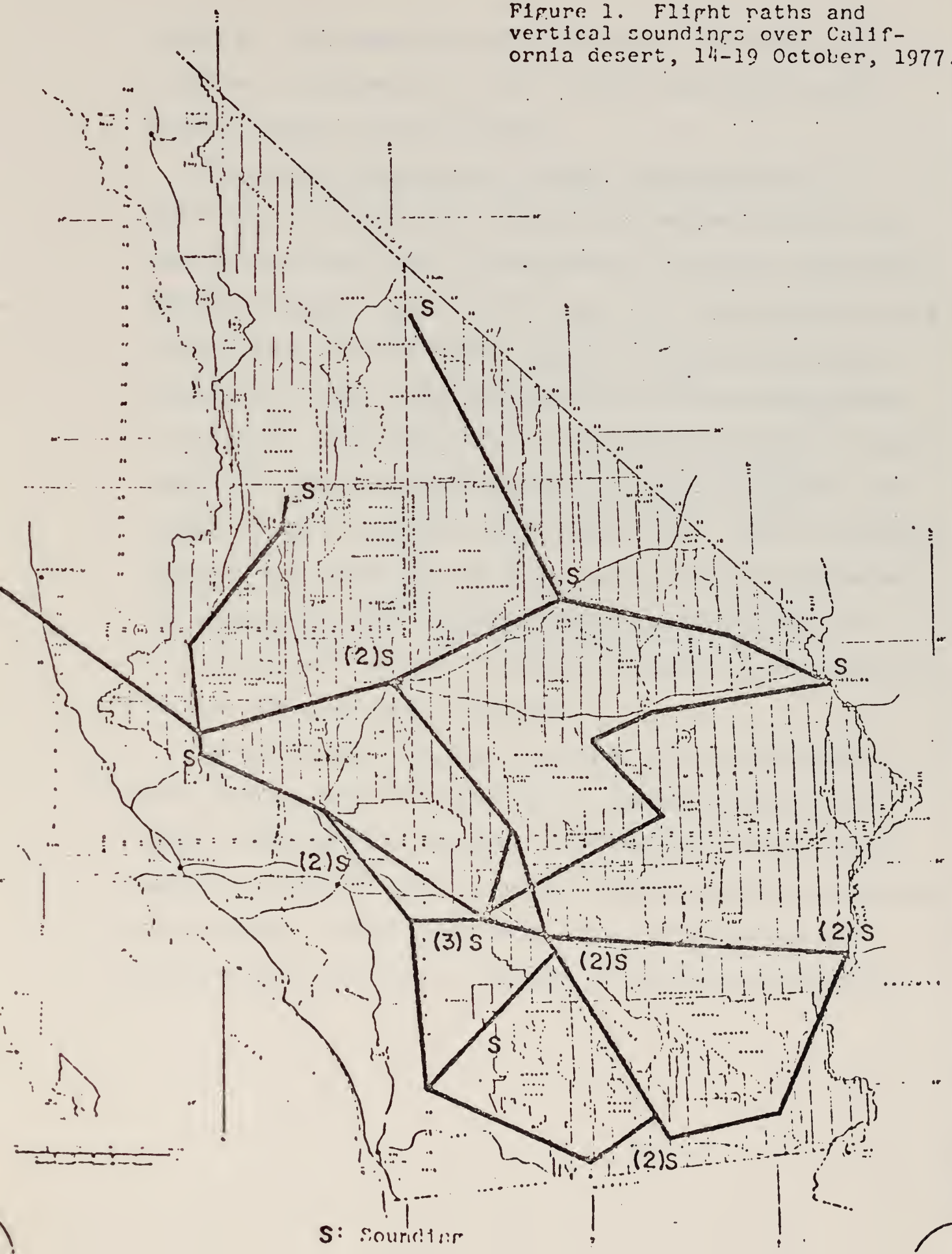
There were 5 to 10 hours of flight on each of the six days, along the various "legs" and in soundings at the points designated in Figure 1.

(ii) Aircraft instruments

A Cessna 172 aircraft was used for air pollution measurements. Its cruising speed is 128 mph. In addition to the pilot there was always a trained observer on board to monitor all instruments, record aircraft position, and note significant weather conditions.

The meteorological instruments consisted of two thermistors for wet-and dry-bulb temperatures mounted in a radiation shield on a strut

Figure 1. Flight paths and vertical soundings over California desert, 14-19 October, 1977.



(Figure 2). The temperature readings (recorded in the cabin of the craft) were calibrated before flight and had an accuracy of $\pm 0.2^{o}C$; the time constant is about 10 seconds.

The pollutants measured were oxidants, carbon monoxide, and particulate mass concentration. (NO_x was not measured because of the expected low concentrations and the generally slow-reacting instruments that are available. It was felt that more flight time would be far more useful to have.) The instruments used were: (a) Daisibi UV (photometric) ozone analyzer (this instrument has an accuracy and threshold of 1 pphm and a time constant of about 5 seconds); (b) Ecolyzer electrochemical CO analyzer (accuracy and threshold of about 1 ppm and a time constant of about 10 seconds); (c) Millipore filter, exposed periodically through a "gun" pointed into the airflow during flight (10-20 minutes). (The photometric or light scattering techniques are very inaccurate, since they depend on empirical relationships between the total mass and the size, shape, and types of particles.)

The oxidant and carbon monoxide readings were recorded on strip chart recorders in the aircraft's cabin. The observer periodically marked the time on these recorders. The filter paper for the particle samples was carefully weighed before the flights and sealed in envelopes after exposure. In addition to being weighed for particulate mass the filters were sent to Dr. C. Leathers of Arizona State University

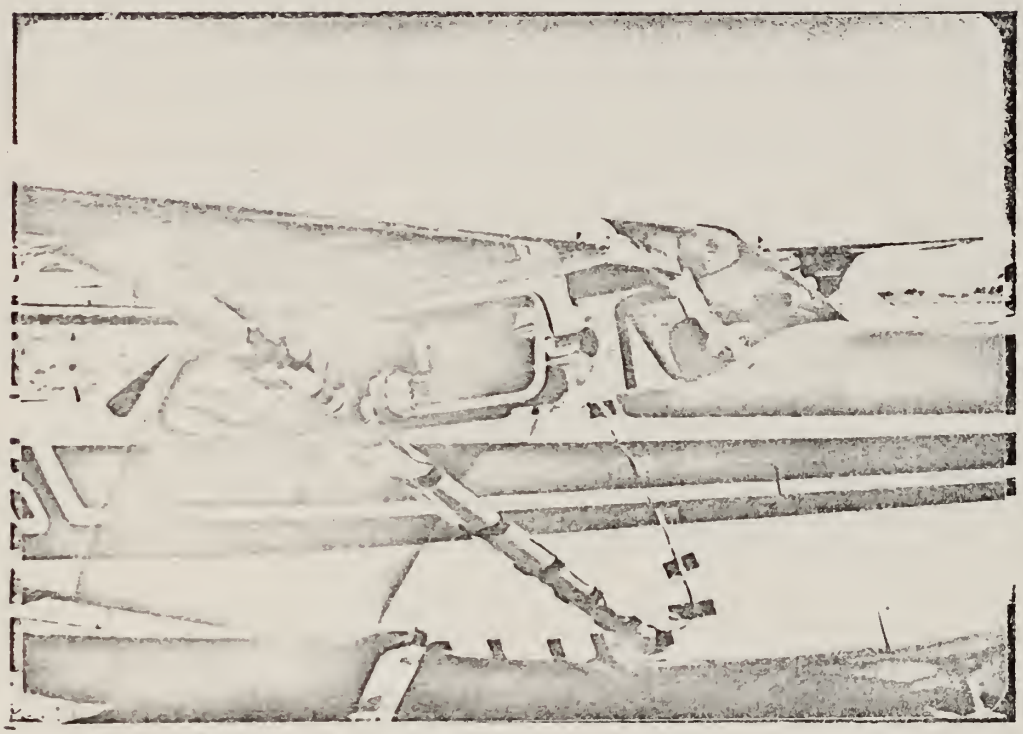


Figure 2. Cessna 172 air sampling aircraft. Mounted on strut: intakes for O_3 and CO analyzers and temperature and wet bulb sensors in radiation shield. In window: intake for particulate sampler.

to be examined for spores, as part of a study of the propagation of Valley Fever by wind-blown dust.

2. Results

The six days of observation spanned a period of transition from clean air with little or no flow from the coastal belt to significant flow from the populated areas to the west and southwest. The following describes the in-flight observations and the meso- and synoptic-scale flows over the area.

(i) 14 October 1977

The flight path is illustrated in Figure 6. The aircraft departed from San Jose at 1330 PST and arrived at Palm Springs at 1800 PST, traversing Gorman, Lancaster, Cajon Pass, and Banning Pass. The air flow was such that over most of the route the concentrations of particulates and of oxidants were low. The route skirted the forward edge of oxidant and CO gradients in Cajon-Banning sector.

The synoptic-scale flows at sealevel (isobars: solid lines) and at 500 mb (contours: dashed lines) are shown in Figure 3. (The desert region of California is hatched.) A trough of low pressure dominates the southwest at sea level, with the "troughline" lying between Yuma and Oakland, i.e., along the western edge of the desert. Thus, the prevailing flow near the surface was from some easterly direction (SE to NE). Onshore flow occurred only in the area southwest of the troughline.

The upper-level circulation over the west is dominated by a ridge, with a closed high near the central coast of California (Figure 3).

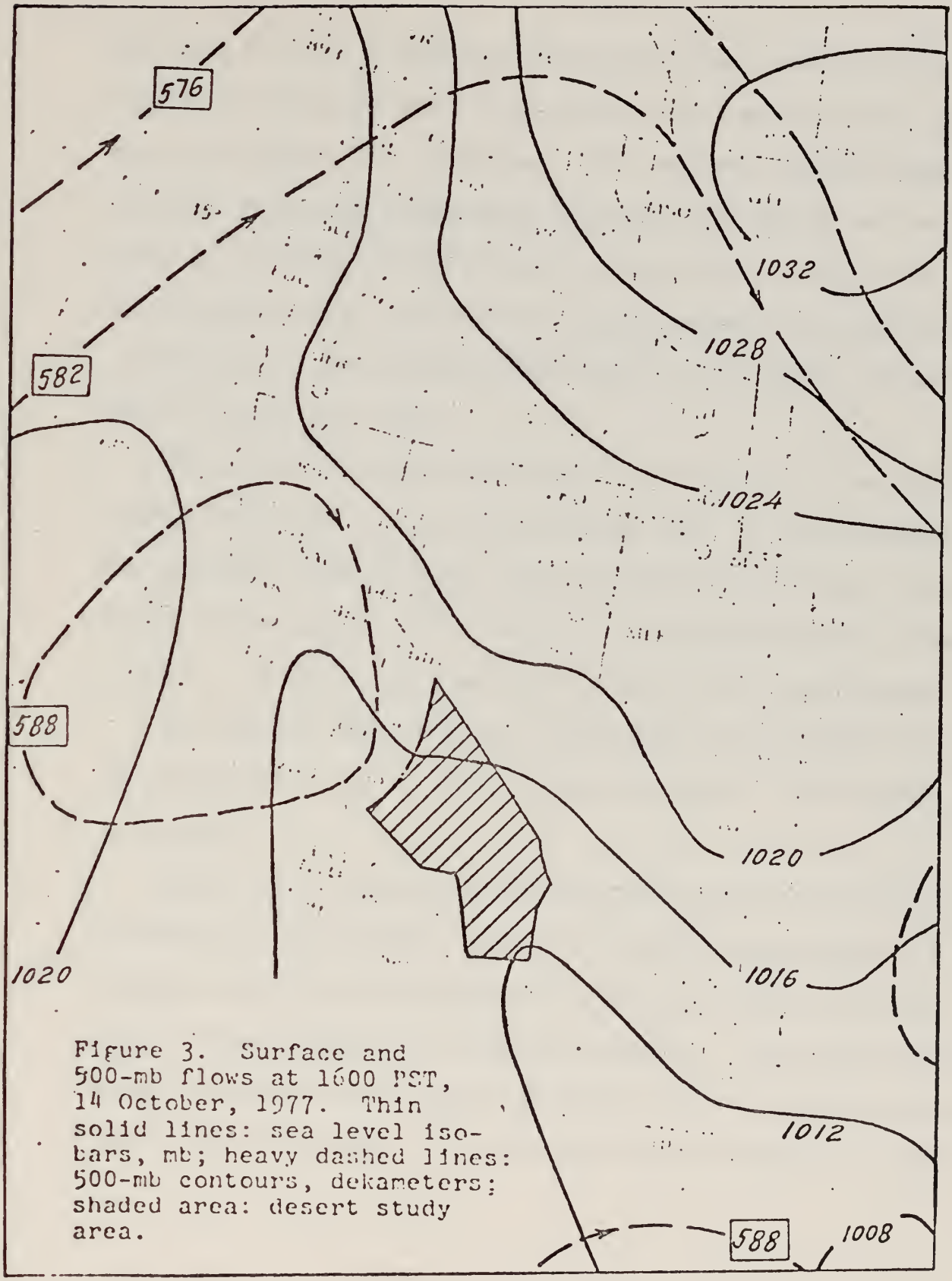


Figure 3. Surface and 500-mb flows at 1600 PST, 14 October, 1977. Thin solid lines: sea level isobars, mb; heavy dashed lines: 500-mb contours, dekameters; shaded area: desert study area.

This kind of flow, in conjunction with the surface pattern, leads to a relatively-deep mixed layer to the east of the trough line and a shallow one in the onshore flow to the west. The northerly flow near the surface, abruptly replaced by southeasterly aloft over the eastern part of the State is dramatically illustrated by the photograph of Figure 15. A clear-cut smog front was observed in the convergence zone between the southwest and easterly winds on both sides of the trough, with haze and smoke in the onshore flow.

The transition between the "coastal" and "desert" air was quite sharply delineated, as shown by the dashed line. On the coastward side, the afternoon temperature was in the 70's near the coast and in the 80's inland. On the desert side of the line, the temperature was in the 80's to 90's in the upper desert and 90's to 100's in the lower desert.

Note the sea breeze effect of the Salton Sea: the temperature in its immediate vicinity is lower and the wind tends to flow outward from the water.

Table 1 gives the estimated maximum mixing depth on October 14 at several observing points, along with some wind measurements. In agreement with the flow characteristics discussed above, the mixing depth increases between the coast and the desert. The maximum mixing depths are based on the soundings of Figure 5 and the maximum surface temperatures for the day. As can be seen from the figure, low-level

inversions over the desert were eradicated by early afternoon but not so over the coast and some inland valleys.

Table 1. Maximum mixing depth (ft) and winds aloft (degrees/knots) on Oct. 14, 1977.

Station	Mixing Depth	Wind at (ASL): 1000'	3000'	6000'
San Diego (MYF)	850	310/09	290/06	080/07
Riverside (FLB)	2750	-	-	-
San Bernardino	-	-	250/06	330/11
Edwards AFB	> 5000	-	260/04	360/04
Palm Springs	> 5000	-	-	-
Thermal	> 5000	-	-	-
Yuma	> 5000	-	020/06	040/09

The edge of the pollution from the Los Angeles Basin was clearly defined at the smog fronts in the major passes, illustrated in Figure 4. In the desert, good visibilities prevailed, indicating little transport eastward on this day. The distributions of ozone and carbon monoxide over the area were analyzed and the former, as observed late in the afternoon, is presented in Figure 6. The aircraft track is shown on the

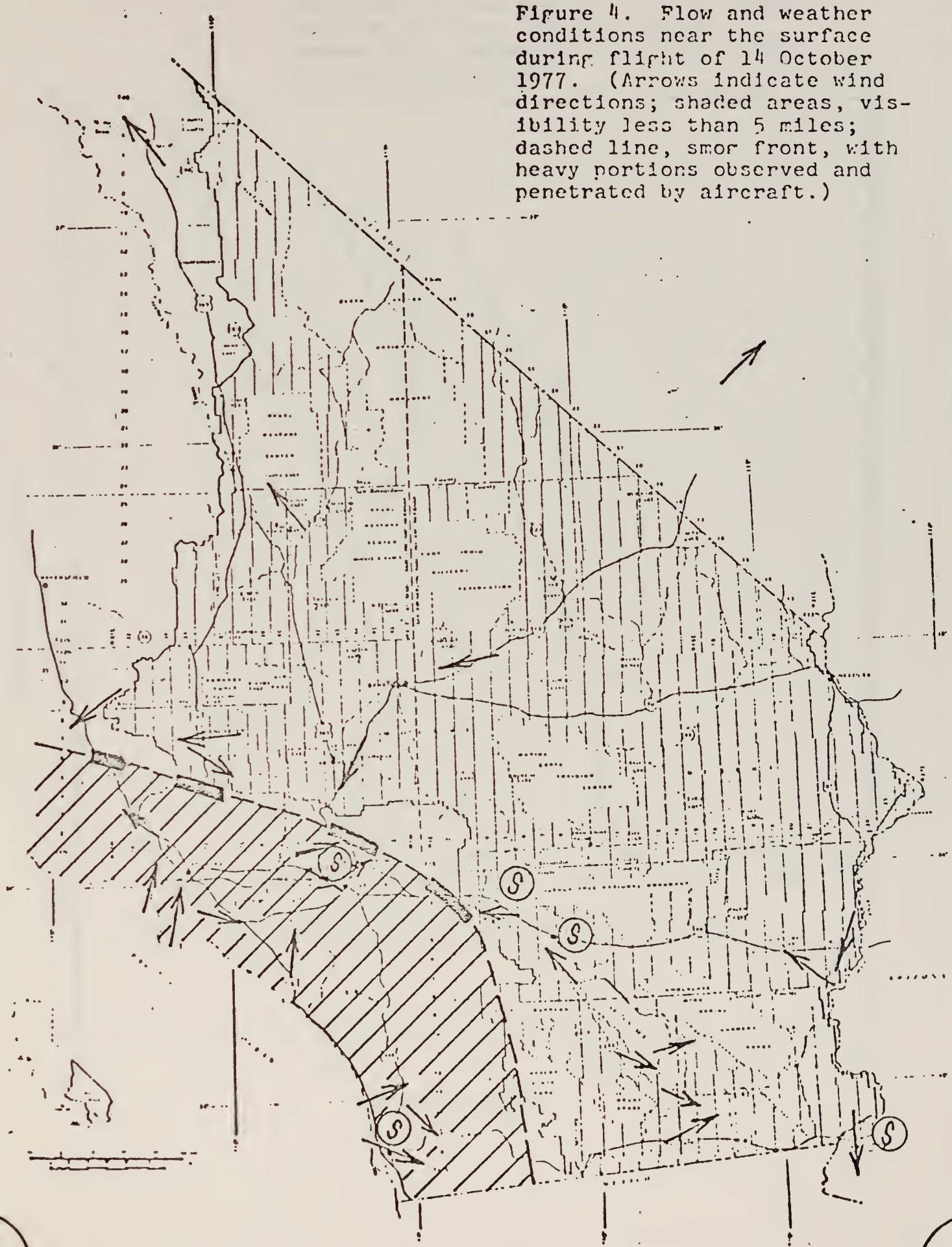
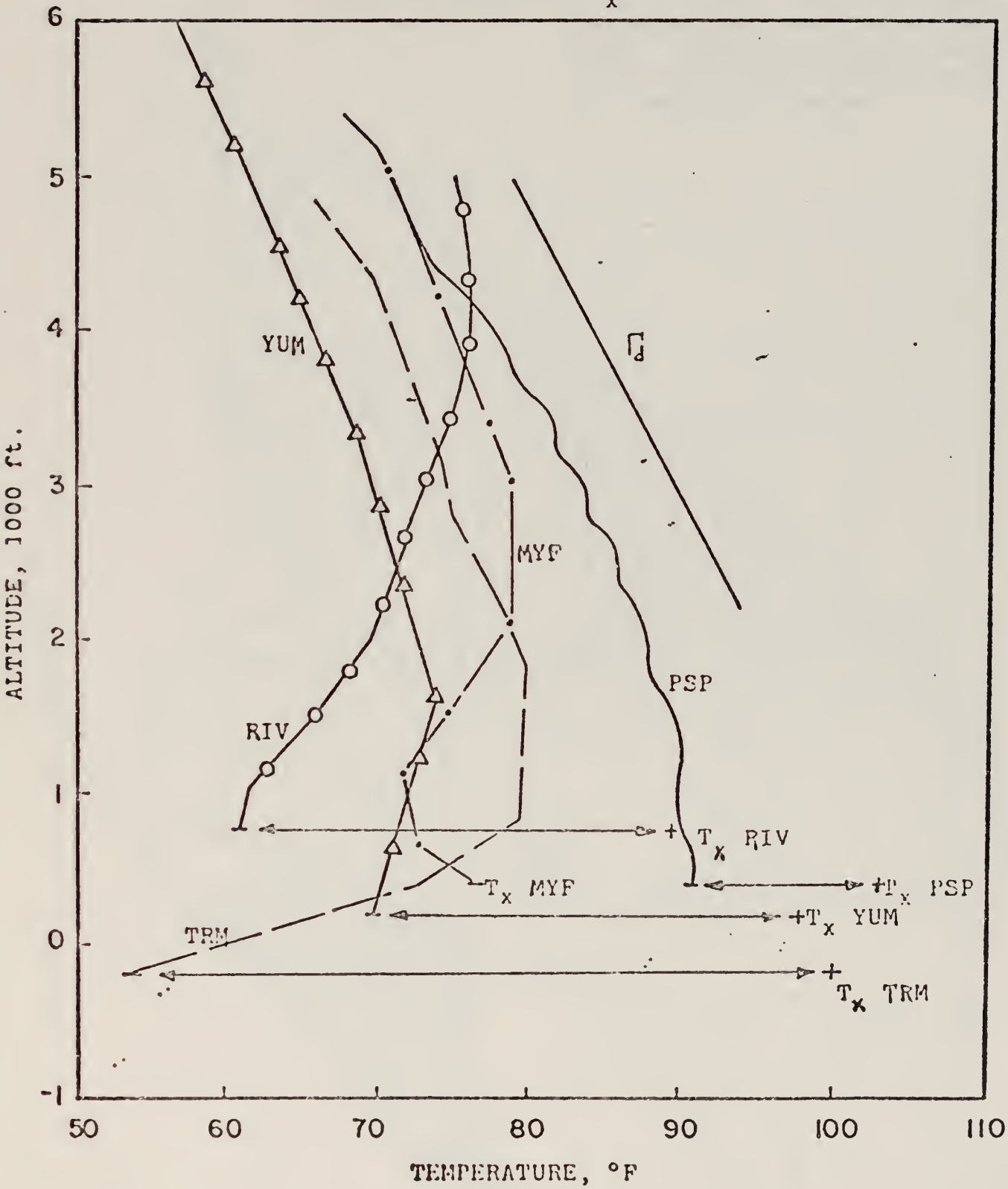


Figure 4. Flow and weather conditions near the surface during flight of 14 October 1977. (Arrows indicate wind directions; shaded areas, visibility less than 5 miles; dashed line, smor front, with heavy portions observed and penetrated by aircraft.)

Figure 5. Temperature soundings for representative coastal (San Diego, MYF, 1600 PST; interior valley (Riverside, RIV, 0300 PST, and desert (Palm Springs, PSP 1725 PST; Thermal, TRM, 0500 PST; Yuma, YUM, 0700 PST) on 14 October 1977. The maximum temperature at each site is indicated by T_x.



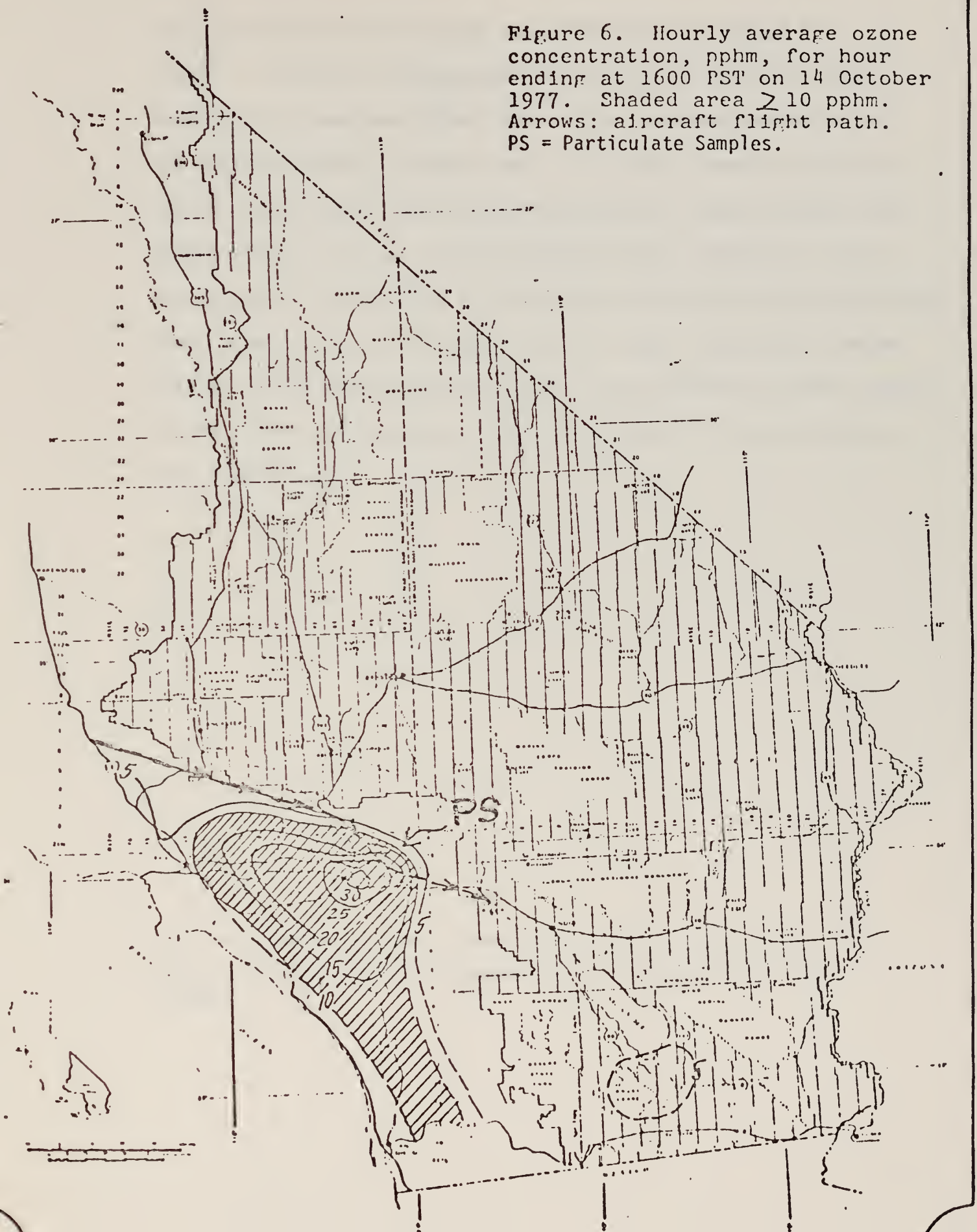


Figure 6. Hourly average ozone concentration, pphm, for hour ending at 1600 PST on 14 October 1977. Shaded area $\geq$ 10 pphm. Arrows: aircraft flight path. PS = Particulate Samples.

same map and the observed ozone concentrations are plotted in Figure 7. Note that the concentration of ozone is high in the Los Angeles Basin (peak near Riverside), with very strong gradients near the mountain passes.* Although there is a slight secondary maximum of concentration south of the Salton Sea, the ozone levels in the desert were generally very low. Carbon monoxide levels exhibited no clear cut pattern of distribution at the surface; aloft, the concentration was almost always near the threshold value of 1 ppm. Particulate concentrations over the desert were also low; at an altitude of 5500' between San Bernardino and Beaumont at 1700 PST the observed concentration was less than 10 $\mu g/m^3$.

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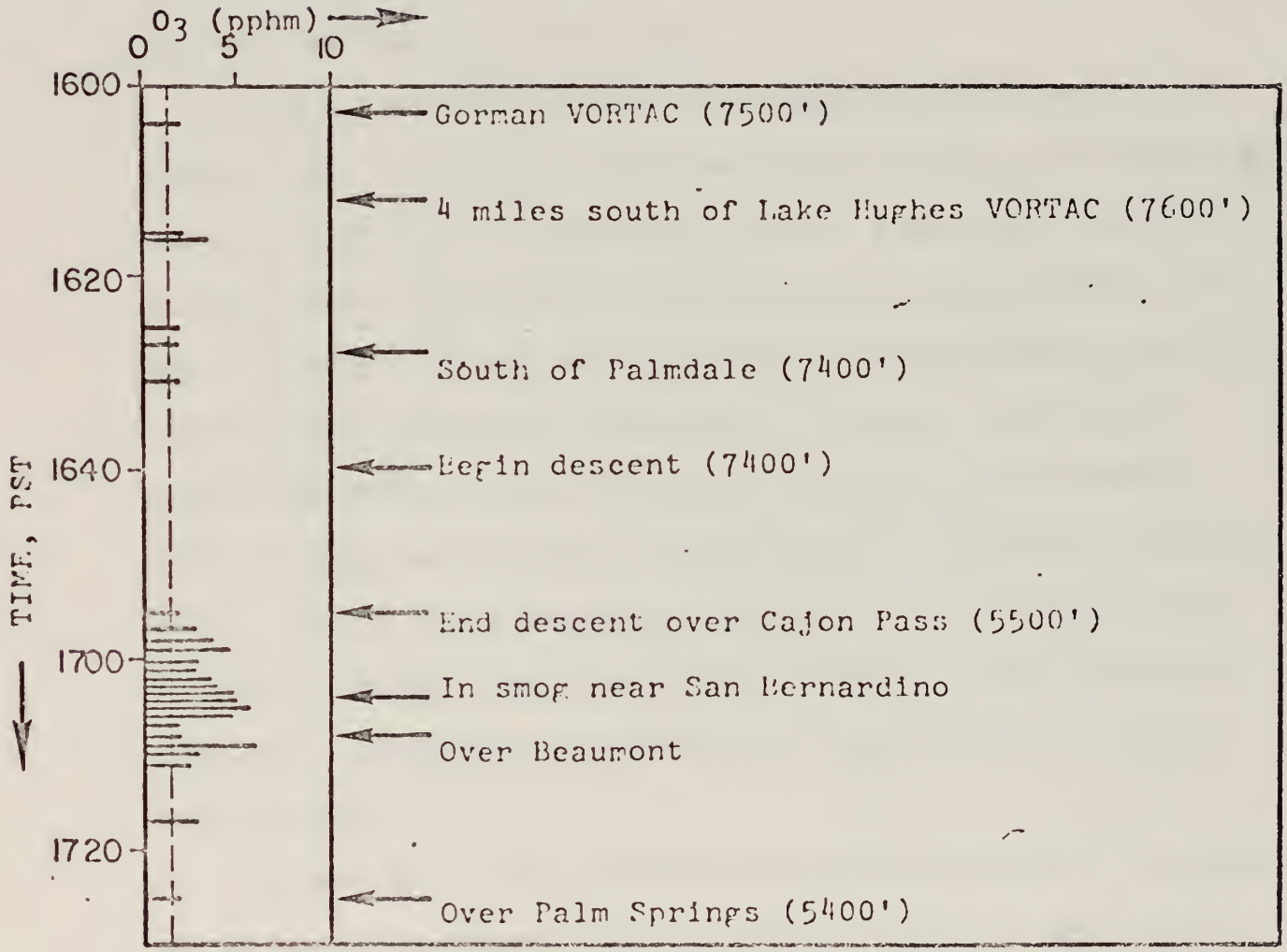
*All air pollution data are summarized in the appendix of this report.

Figure 7. Ozone concentration measured from aircraft between Gorman and Palm Springs, 1600-1730 PST, 14 Oct 1977. (Concentrations less than 1.5 pphm- dashed line - are not shown.)



(ii) 15 October 1977

The survey concentrated on the southern portion of the study area on this day (Figure 10). Most flights were conducted at elevations of less than 300 feet above the ground.

There had been some changes in the synoptic scale flow since the previous day. The ridge at 500 mb had shifted eastward, with decreasing 500-mb heights over the southwestern states. A weak front neared the northern coast of California, while the thermal trough persisted over the study area. The high over Montana moved southeastward, leading to increased pressure in Utah and Arizona; as a result, the pressure gradient on the east side of the thermal trough increased somewhat, giving stronger easterly flow over the deserts. This type of synoptic pattern induces a weak Santa Ana flow in some of the mountain passes. In general, however, the air pollution conditions of the previous day prevailed: low mixing depth over the Los Angeles Basin, high depth over the desert.

The smog front of the previous day had retreated toward the coast, as can be seen by comparing Figures 8 and 4. Otherwise the flow near the surface was quite similar to that of the previous day: westerly flow along the coast, generally easterly over the interior. Some idea of the maximum mixing depths during the day can be obtained from the temperature soundings and maximum temperatures shown in Figure 9. Over

Figure 8. Same as Figure 4, except for 1600 PST, 15 Oct. 1977.

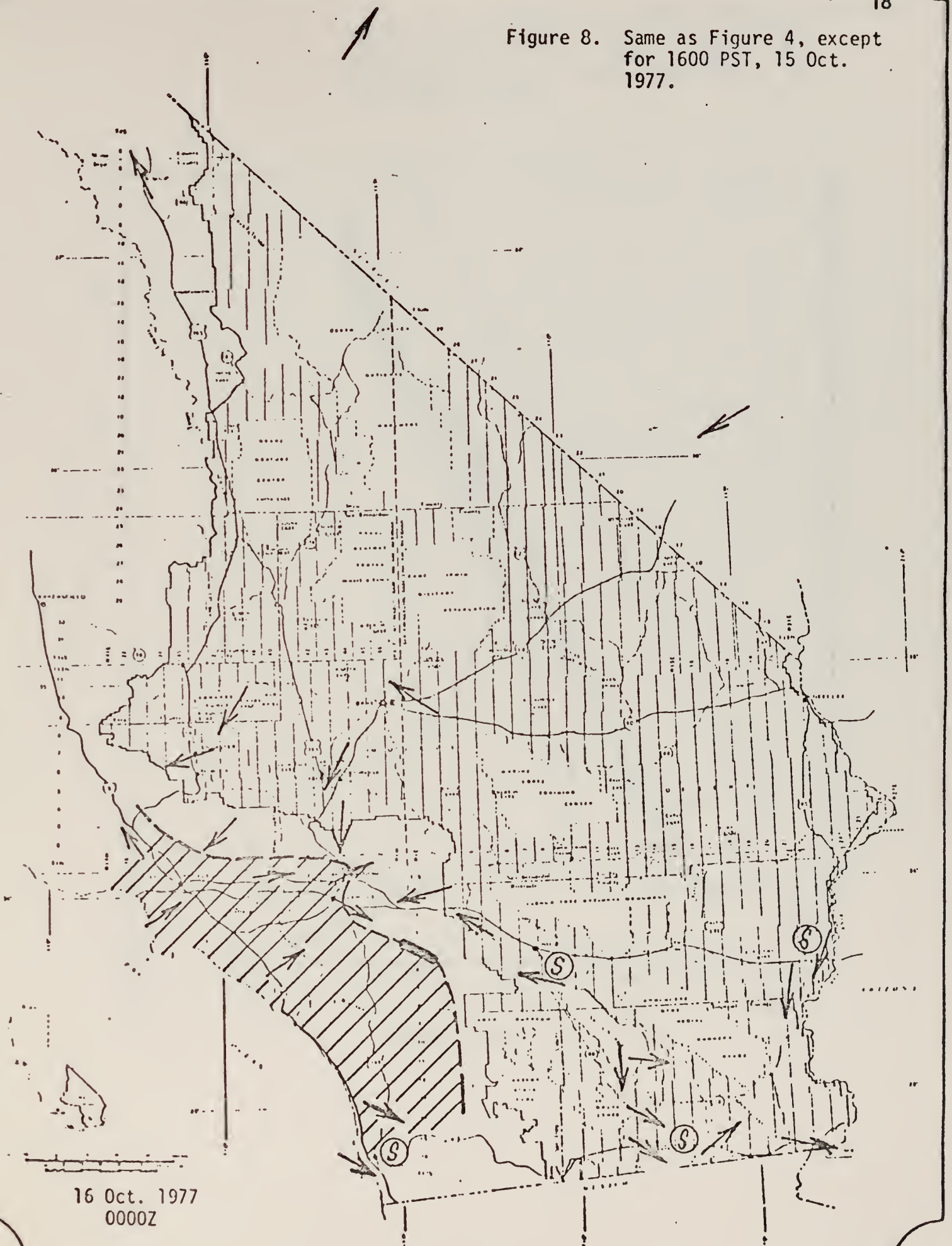
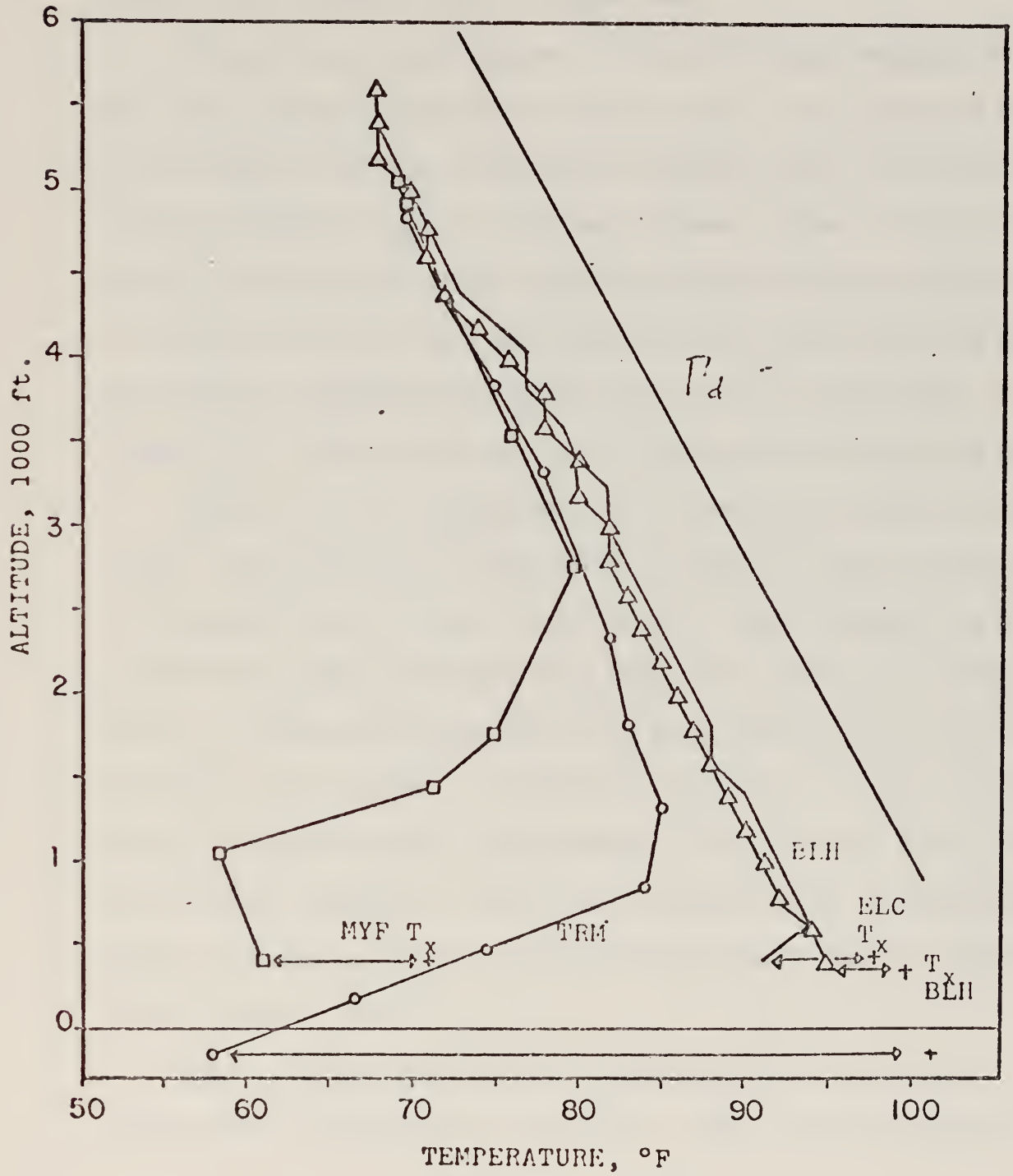


Figure 9. Temperature soundings at San Diego (MYF, 0400 PST), Thermal (TRM, 0500 PST), El Centro (ELC, 1439 PST), and Blythe (BLH, 1346 PST), on 15 October 1977.



the desert, the mixing depth was extremely great while over coastal areas it was generally less than 1000 feet.

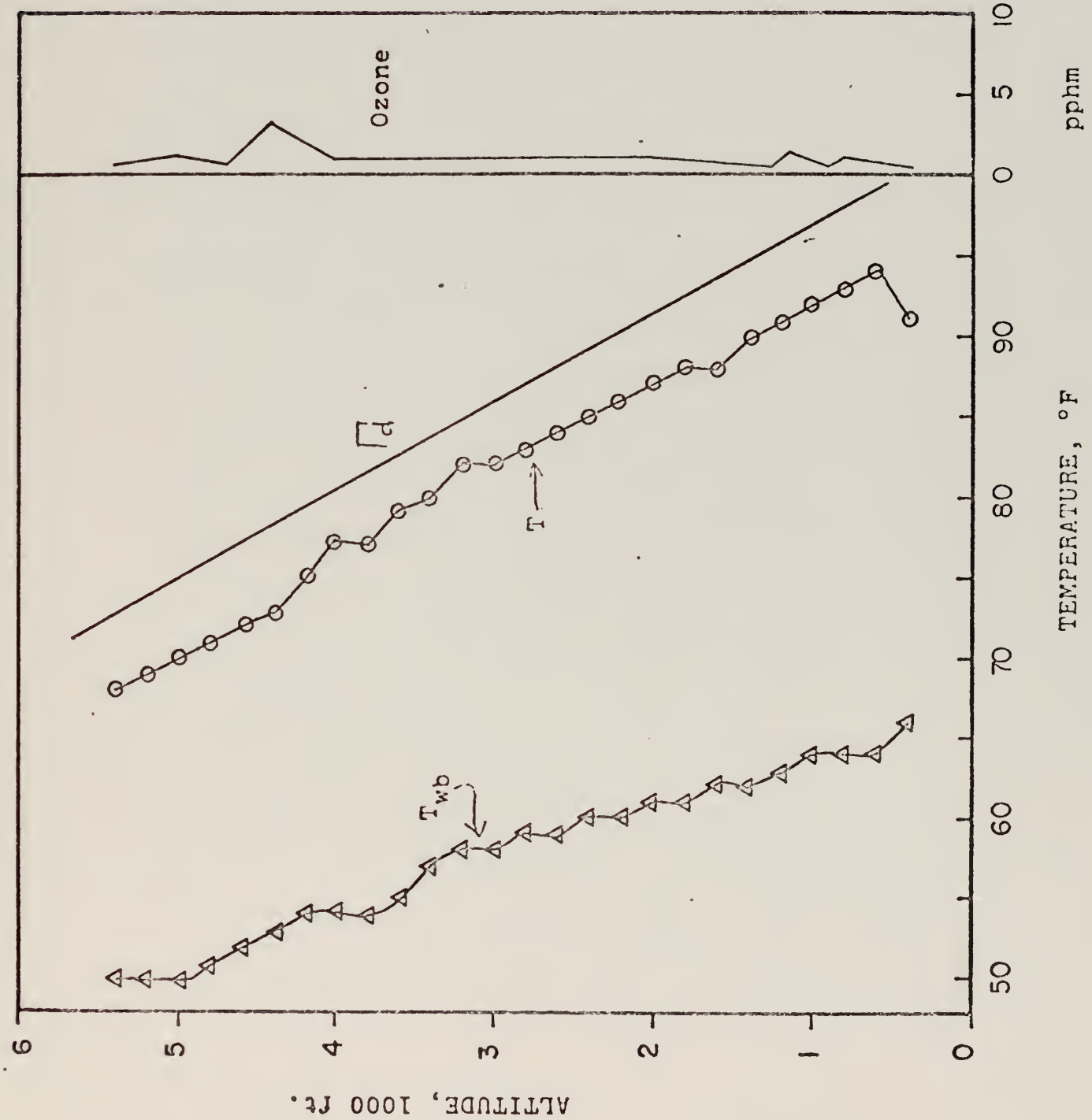
The horizontal distributions of ozone and carbon monoxide over the study area were analyzed for this day also. The retreat of the forward edge of the smog toward the Los Angeles Basin is further illustrated by the isopleths of ozone in the late afternoon shown in Figure 10. The peak concentrations on either side of the smog front were unchanged from the previous day. The aircraft flight path was almost entirely east of the principal pollution area except near the end of the flight (Figure 10). The gradient was not as strong as on the previous day.

Almost all aircraft measurements of ozone and CO, taken largely in the "clean" desert air, were below 1.5 pphm and 1 ppm, respectively. A few notable exceptions were the following: Over Palm Springs at 1153 PST the ozone increased from 2 pphm at the surface to 6 pphm at at 750'. This minor maximum aloft was found sporadically as far east as 24 miles east of Thermal. At Blythe at 1345 PST, the ozone reached a peak of 5.5 pphm and CO 9 ppm, probably in the wash of a jet aircraft. The vertical soundings at Blythe and El Centro showed no significant maxima of either CO or ozone, except for the small peak of ozone near 4400' shown in Figure 11.

Again, the dust concentrations were found to be very low ($< 20\ \mu g/m^3$) everywhere over the desert. There were some particulate

Figure 10. Hourly average ozone concentration, pphm, for hour ending 1600 PST, 15 Oct. 1977. Shaded area ≥ 10 pphm. Arrows: aircraft flight track.

Figure 11. Aircraft sounding of dry- and wet-bulb temperatures and ozone concentration over Blythe at 1346 PST, 15 October 1977.



sources observed from the aircraft. For example, dust was being raised by tractors near El Centro and smog could be seen over Mexicali.

(iii) 16 October 1977

The persistence of the easterly flow over most of the study region and the request by BLM that dust samples be taken over a motorcycle race near Plaster City (west of El Centro) led to a modification of the original flight plans for this day. The actual flights are shown in Figure 13.

The large scale synoptic flow near the end of the flight period is shown in Figure 12. A weak cutoff low had developed off the coast of Northern California (40^{o}N, 125^{o}W) at 500 mb and a weak front had moved into California. The pressure gradient to the east of the surface low centered over Yuma was weaker. The result of these synoptic changes was leading to a distinct weakening of the easterly flow over the desert. The southwest winds in the coastal belt were intensifying near the end of the period and it seemed likely that marine air would deepen and begin to invade the interior on the following day (17 October 1977). Some convective activity began to appear in Western Arizona as moist air began to move in from the Gulf of California.

The smog front did not move beyond the edge of the Los Angeles Basin, as illustrated in Figure 13. Its position at 1400 PST is estimated from aircraft observations (solid line) and surface weather reports (1300 PST, dashed line). However, in mid-afternoon, the front was moving eastward quite rapidly, as can be seen from the aircraft-

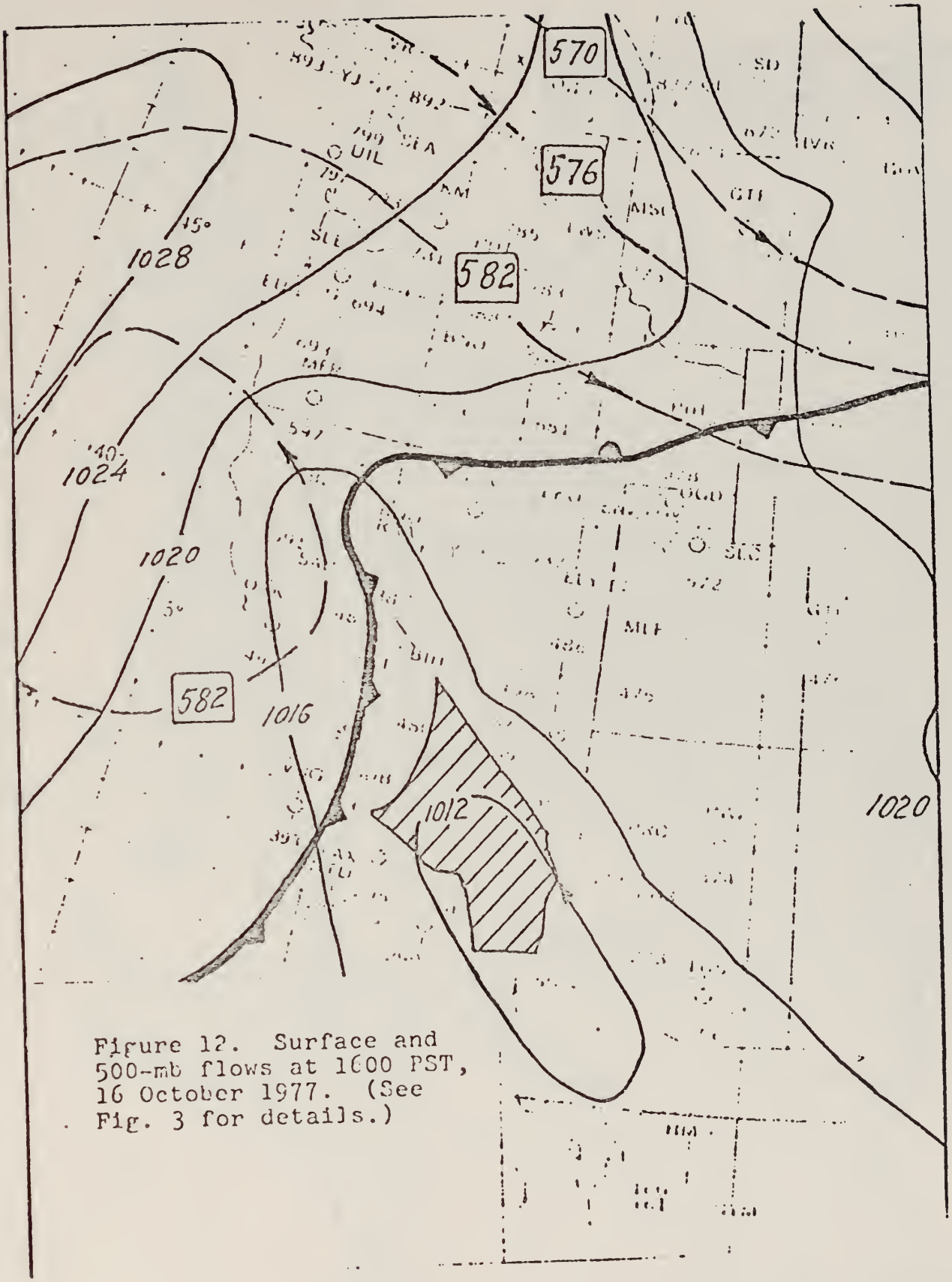


Figure 12. Surface and 500-mb flows at 1600 PST, 16 October 1977. (See Fig. 3 for details.)

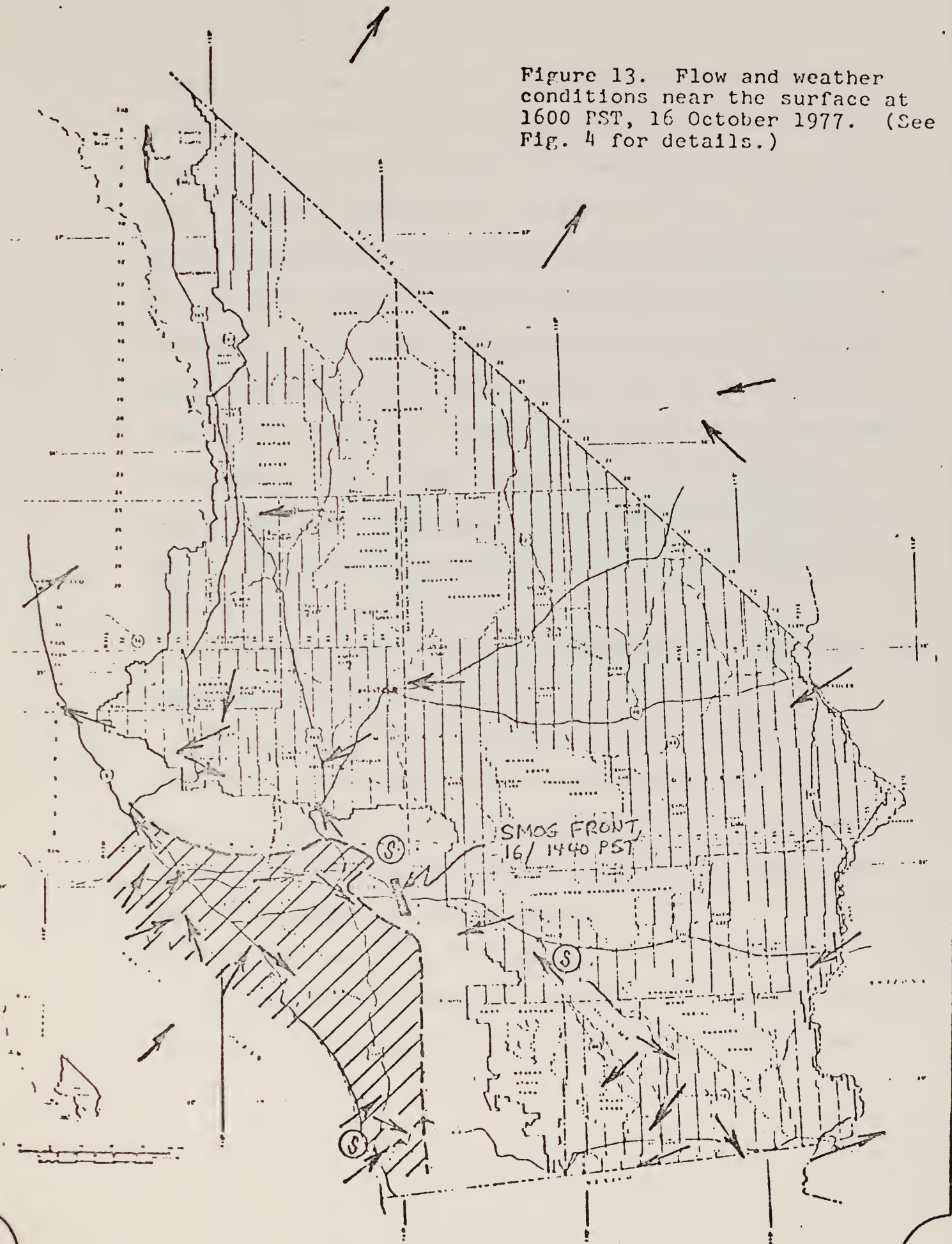


Figure 13. Flow and weather conditions near the surface at 1600 PST, 16 October 1977. (See Fig. 4 for details.)

determined position at 1440 PST. (The enhanced eastward transport was undoubtedly associated with the increased flow from the west as the cold front shown in Figure 12 moved into Southern California. The winds at mountain stations such as Sandberg, Mt. Wilson, and Crestline changed from northerly to southerly.) The visibility in the Los Angeles Basin was generally poor (Figure 14), while excellent (40-50 miles) in the desert, as was the case during the preceding two days. Within the desert, only areas near the Mexican border (e.g., at Imperial) had somewhat poorer visibility, evidently due to some transport from south of the border. The air mass differences across the smog front were again evident from the temperature field, ranging from the 70's along the coast to the 80's over the interior valley and upper desert to 90-100^{o}F over the lower desert.

The shifting winds with height are dramatically illustrated by the photograph of Figure 15.

The soundings presented in Figure 16 serve to illustrate the variations in mixing depth between coast and desert. Over the south coast, the depth of the marine air was about 1000 feet, an increase of 150 feet over the previous day, while in the north the layer had almost doubled in thickness (to 1400' at Vandenberg). Over the desert the mixing depth was well over 5000', as it had been on the previous days.

The horizontal distribution of oxidants at the surface (Figure 17) is not much different than that of the previous day. The maximum

Figure 14. Smog front west of Hemet at 3300' at 1359 PST, 16 Oct. 1977.

Figure 15. Smoke plumes observed from El Centro at an elevation of 1100' looking northeastward at 0914 PST, 16 Oct. 1977. Note that the wind was northwest near the surface, southeast aloft.

Figure 16. Temperature soundings at San Diego (MYF, 0400 PST), Thermal (TRM, 0500 PST), and Redlands (1428 PST).

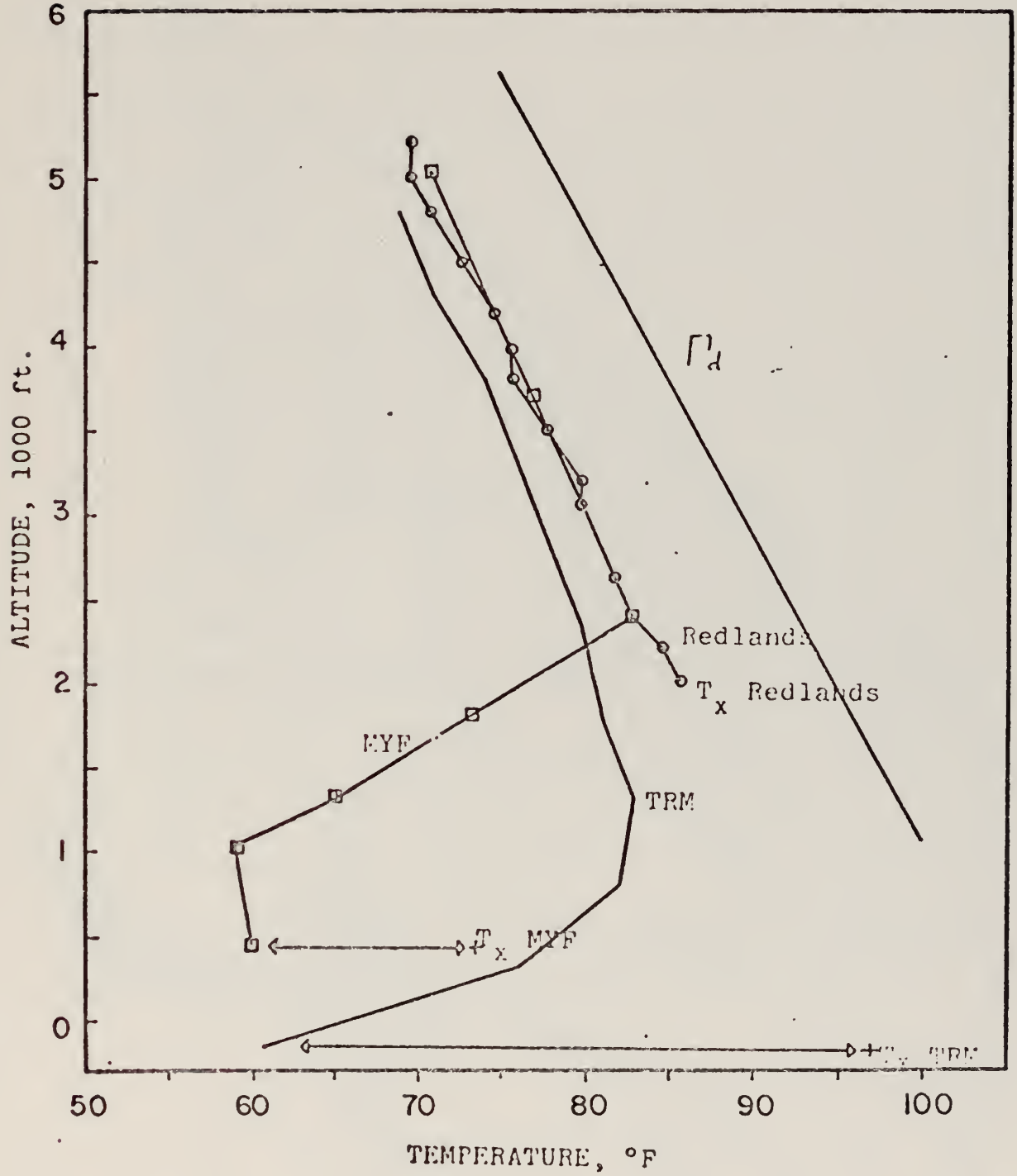
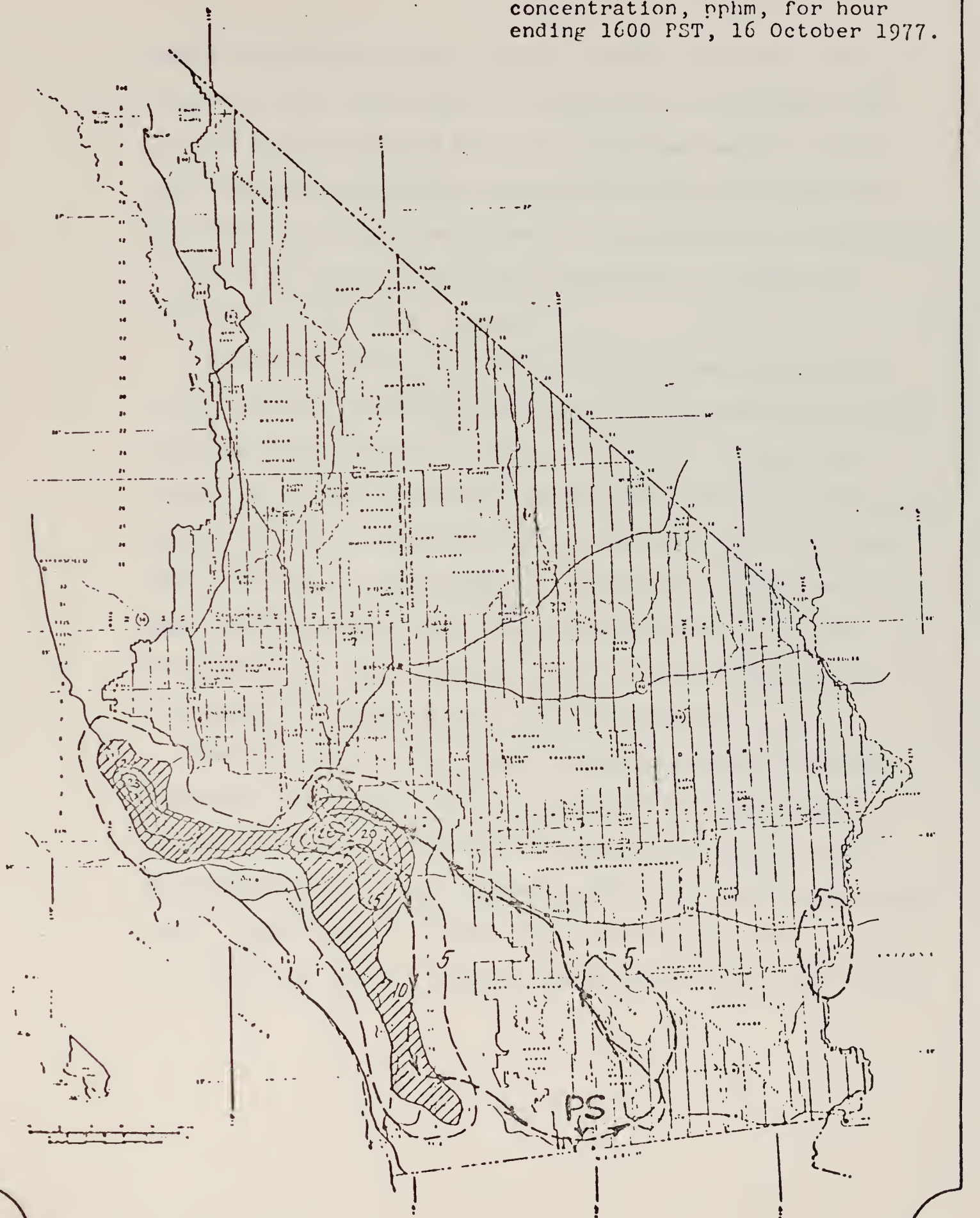


Figure 17. Hourly average ozone concentration, pphm, for hour ending 1600 PST, 16 October 1977.



gradient along the mountains is perhaps slightly more intense than on the previous day. This change is probably due to the increased flow from the west and increased mixing depth in the marine air. The aircraft measurements showed that the desert air east of the smog front continued to have low concentrations of all constituents (< 2 pphm of O_3, ~ 1 ppm of CO) except in the Plaster City-Imperial area where the motorcycle race was being conducted.

The aircraft flew across the area of strong ozone concentration in the vicinity of San Bernardino (Figure 17). A sounding made over the San Bernardino-Redlands area is shown in Figure 18. Of particular interest is the peak of 25 pphm observed at 3800' (1000' above the ground) Evidently there are intrusions of high-concentration air aloft. Under some circumstances, these laminae may be carried far eastward over the desert and brought down to the surface where there vertical mixing penetrates these layers. This may explain the high concentrations of ozone observed in Furnace Creek by other investigators.

The ARB network of high volume samplers was operating on this day. Twenty-four hour samples of particulates showed high concentrations in the marine air west of the smog front (200-300 $\mu g/m^3$), and low levels in the desert east of the front (40-60 $\mu g/m^3$). The aircraft measurements over the desert showed low levels aloft, generally less than 20 $\mu g/m^3$. As noted earlier special low-level measurements were made in the visible

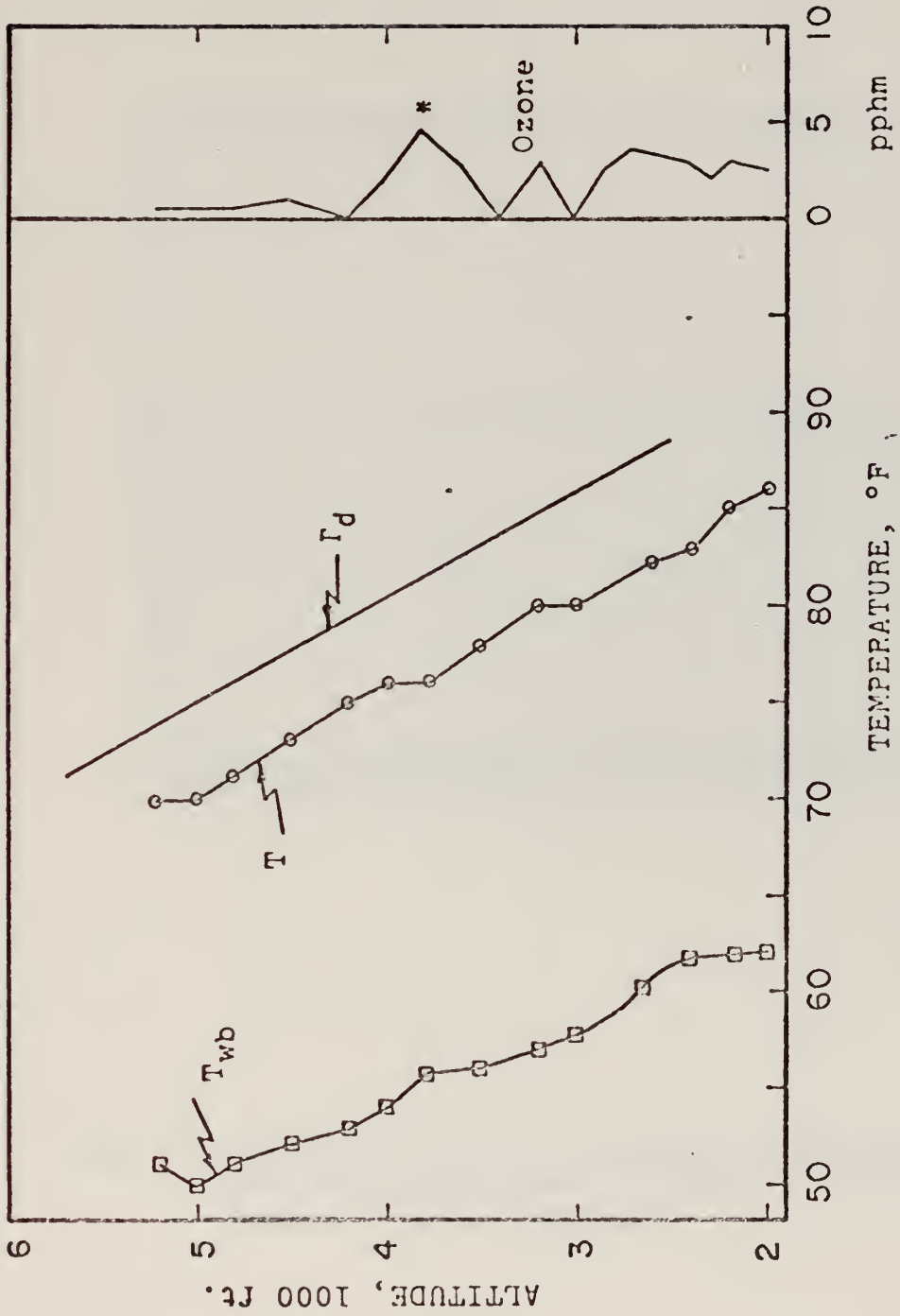


Figure 18. Aircraft sounding of dry- and wet-bulb temperatures and ozone concentration over Redlands at 1428 PST, 16 October 1977. (*Peak of 25 pphm was recorded at this altitude northwest of San Bernardino.)

Figure 19. Dust plume raised by a motorcycle race, taken at about 200' above ground level at 0900 PST, 16 Oct. 1977. Mexico is in the background.

Figure 20. Another view of the dust plume raised by a motorcycle race, taken at about 100' above ground level at about 0900 PST, 16 Oct. 1977.

dust plume emanating from the motorcycle race near Plaster City. At an altitude of 100 feet above the ground, the concentration was about 370 $\mu g/m^3$. Figures 19 and 20 are photographs of the dust plume.

(iv) 17 October 1977

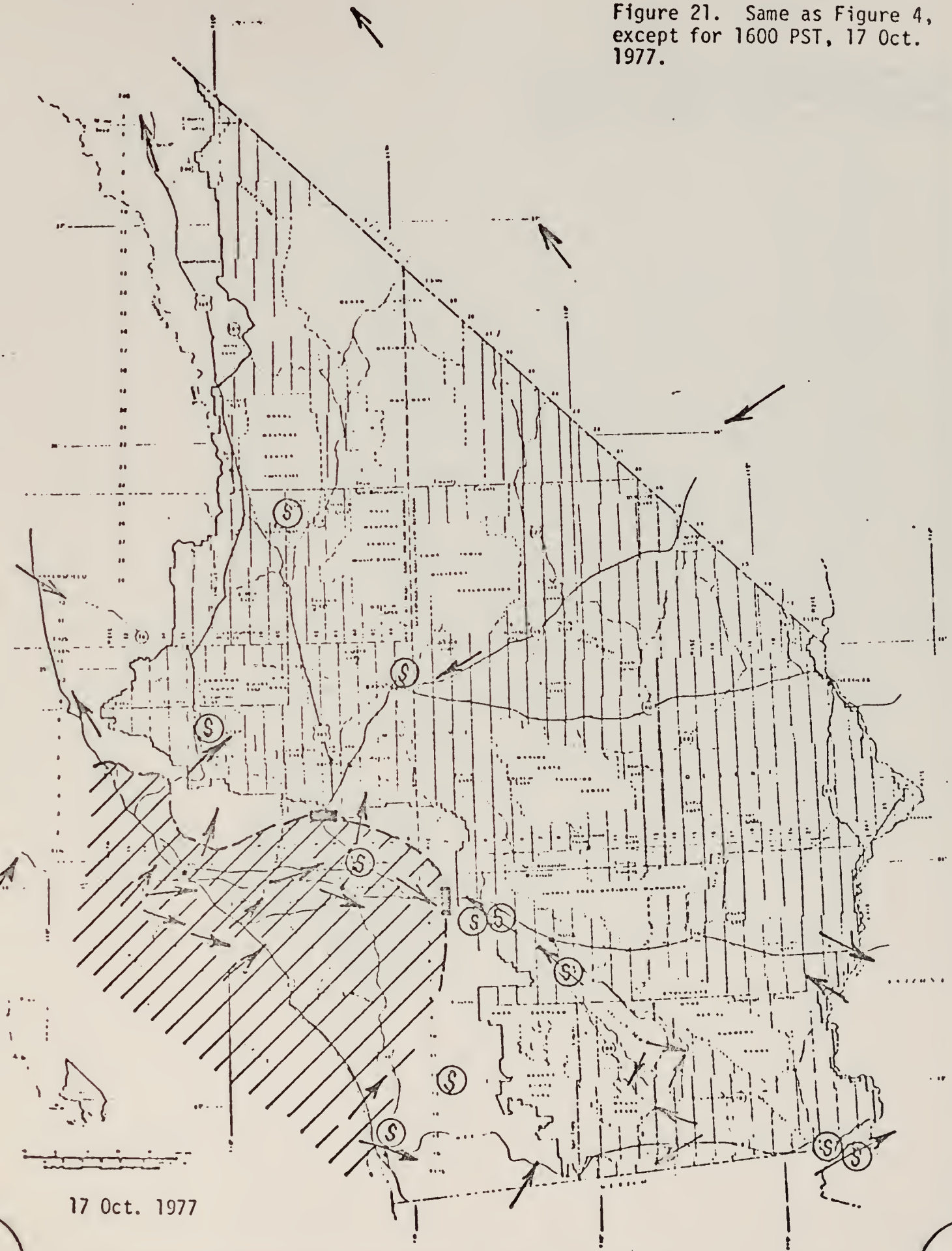
As the marine layer deepened and began to spill eastward from the Los Angeles Basin, operations were shifted to the north and northwest of Palm Springs (Figure 22). The weak front moved across the study area and the cyclone at 500 mb had moved to a point off the coast of Southern California. The increased southerly flow aloft could be expected to further deepen the marine air along the coast and increase the flux of pollutants into the desert.

The smog front clearly moved inland toward the desert, as illustrated by Figure 21. By this time the marine layer had deepened sufficiently to allow polluted air to cross over the mountains as well as move through the passes. There is some evidence that polluted layers move aloft over the desert and perhaps reach the surface through convection at a considerable distance from the source. Note the sea breeze circulation associated with the Salton Sea.

The temperature soundings of Figures 23a and b show how the mixing depth changed with the new flow pattern. At San Diego the maximum mixing depth increased to 1300'; at San Bernardino to 2600'; at China Lake, > 3000'; and over most of the desert, > 5000' (8700' at Yuma).

The flux of ozone into the desert is evident from the isopleths of concentration at the surface given in Figure 24. The gradient of

Figure 21. Same as Figure 4, except for 1600 PST, 17 Oct. 1977.



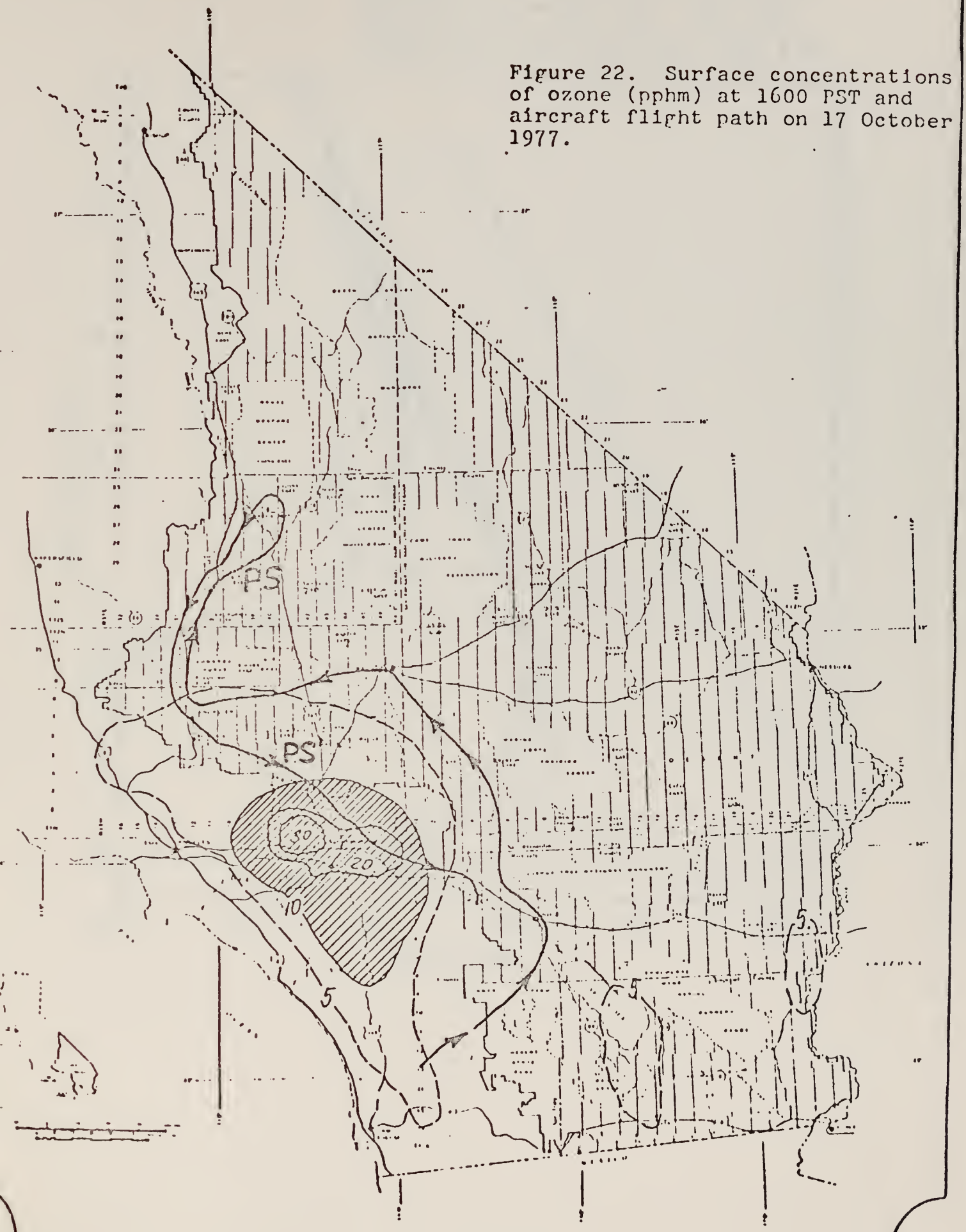


Figure 22. Surface concentrations of ozone (pphm) at 1600 PST and aircraft flight path on 17 October 1977.

Figure 23a. Temperature soundings at Thermal (TRM, 0500 and 0802 PST), Ramona (RAM, 0642 PST), Barstow (BAR, 0857 PST), Lancaster (0948 PST), and Yuma (YUM, 0900 PST) on 17 October 1977.

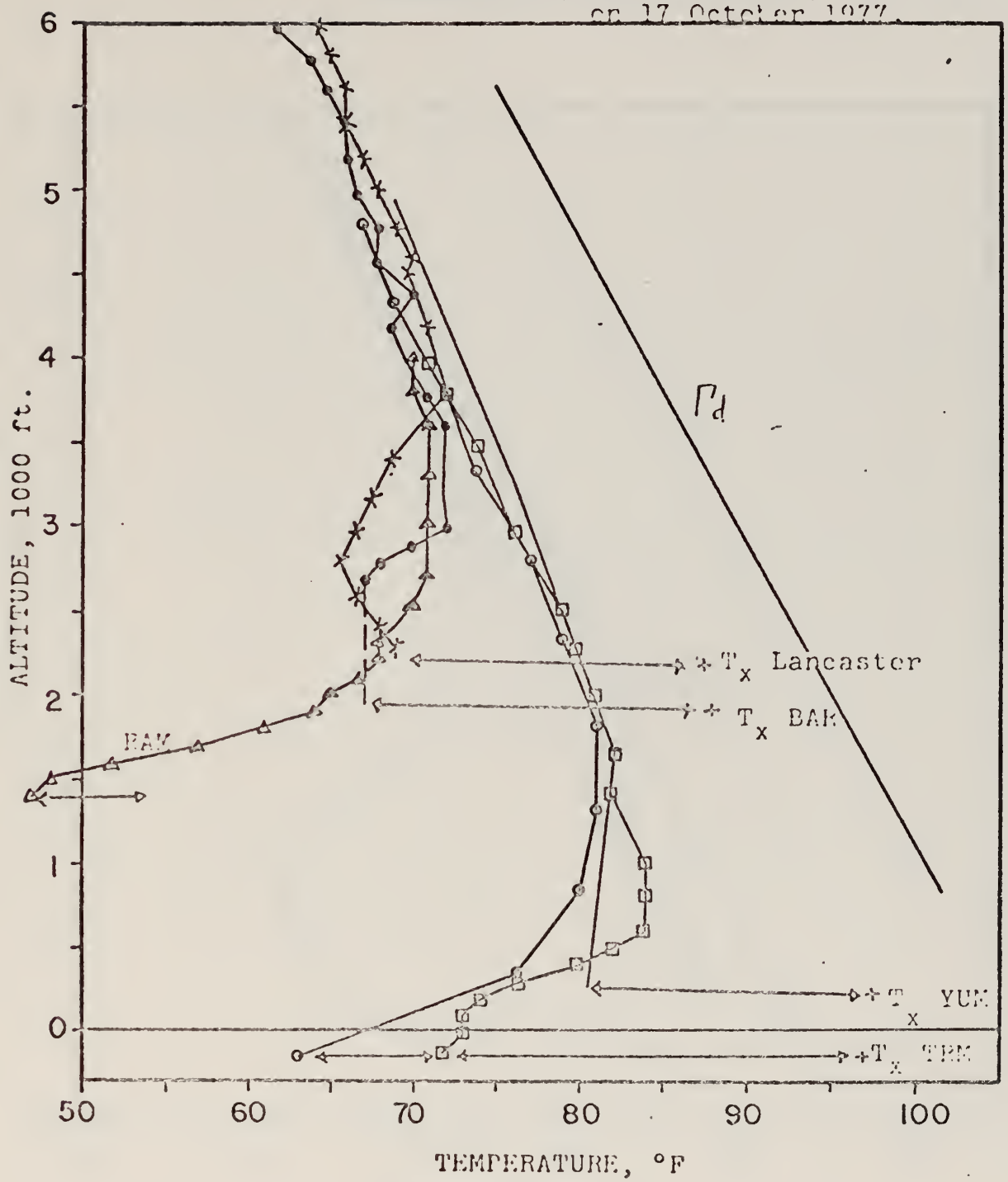
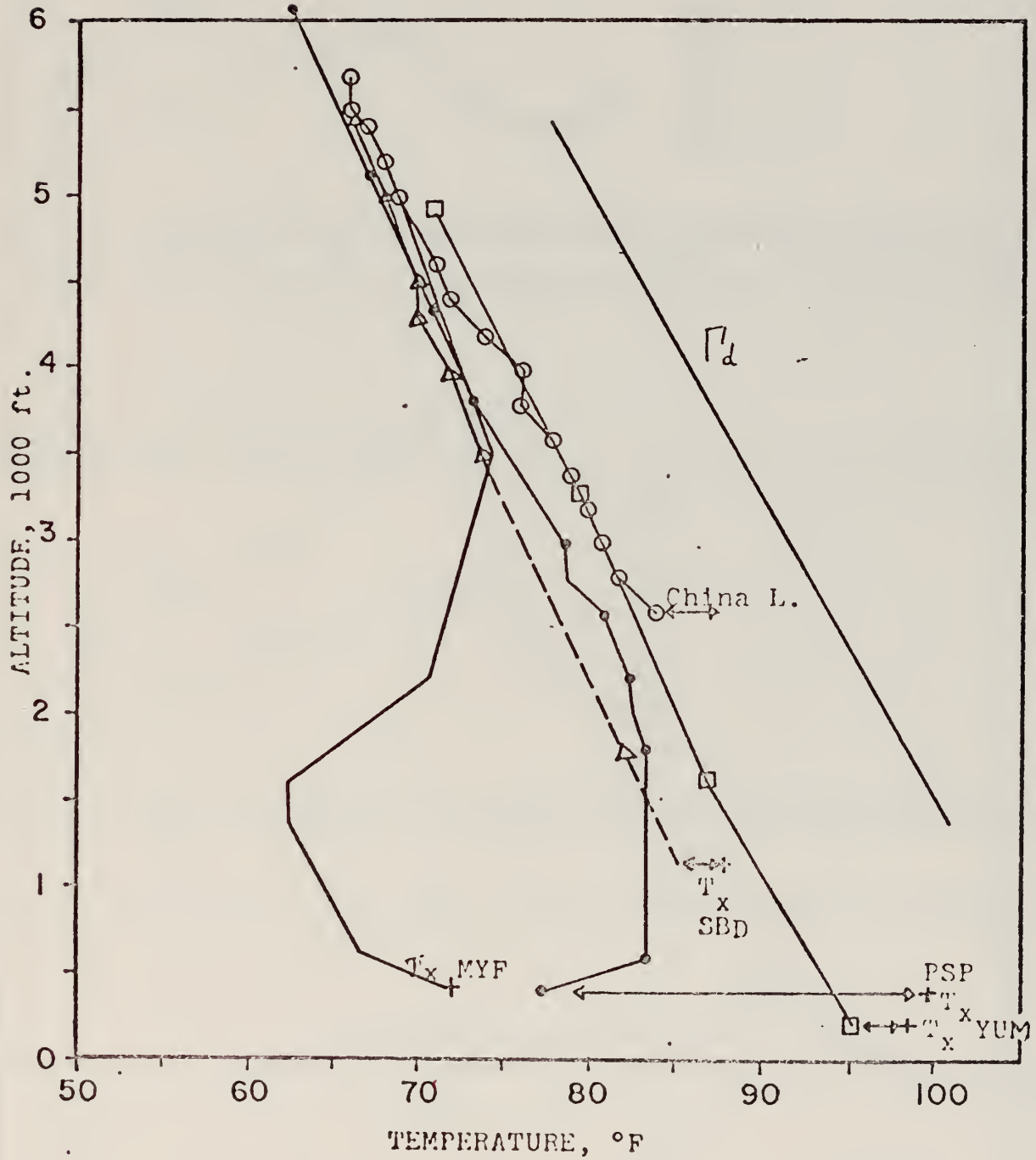


Figure 23b. Temperature soundings at China Lake (1205 PST), San Bernardino (SBD, 1437 PST), Palm Springs (PSP, 2030 PST), Yuma (YUM, 1300 PST), and San Diego (MYF, 1600 PST) on 17 October, 1977.



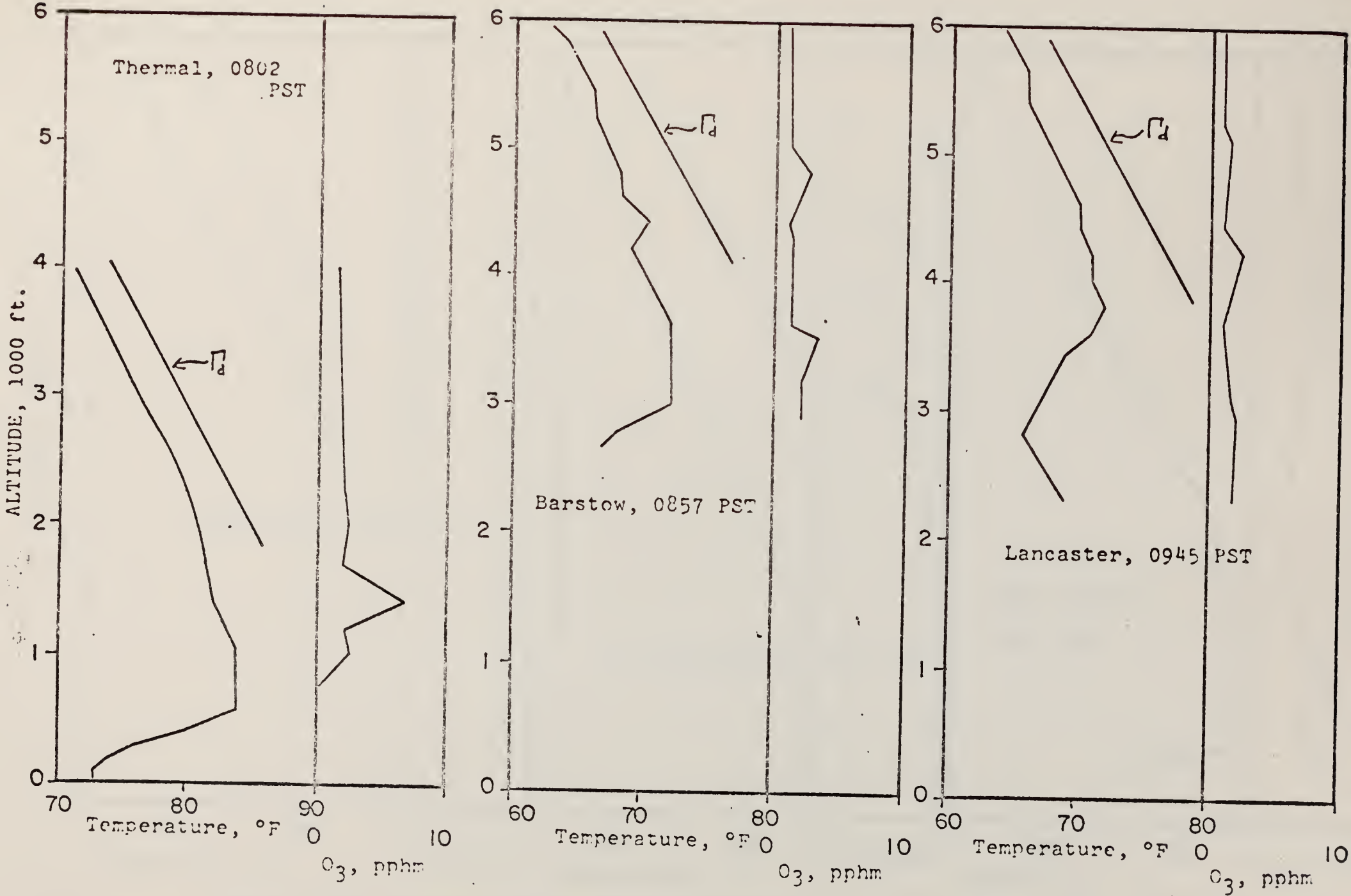


Figure 24a. Temperature and ozone concentration soundings, 17 Oct. 1977

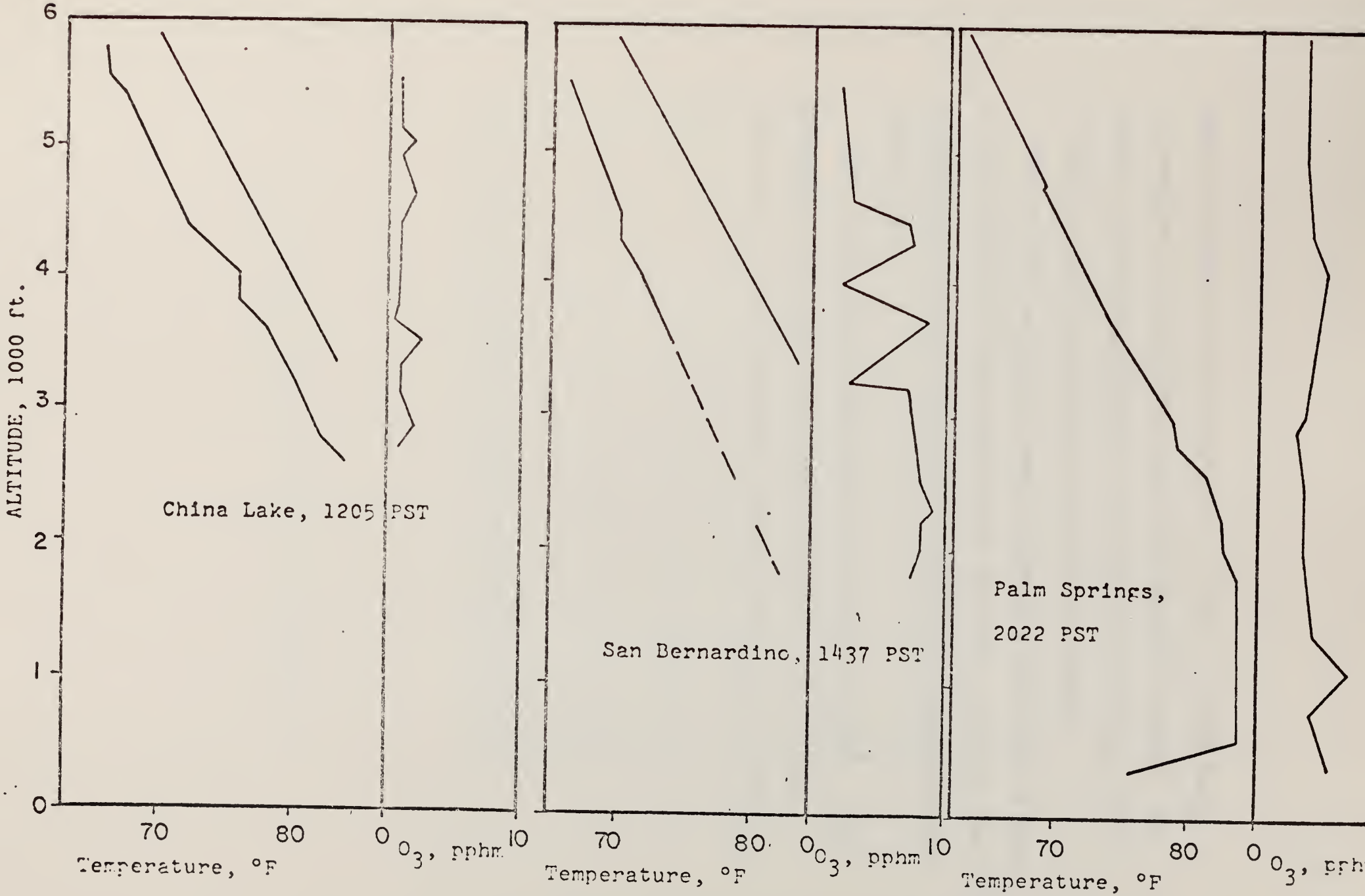


Figure 24b. Temperature and ozone concentration soundings, 17 Oct. 1977

ozone was strongest along the north side of the Los Angeles Basin. The transport of ozone could be seen from individual stations. For example, the maximum concentration (12 pphm) at Palm Springs occurred at 2000 PST, possibly following a wind shift to northwest.

The aircraft soundings of ozone (Figure 24 a and b) show "streaks" of high concentration over large areas of the desert. However, the density of soundings is far from sufficient to establish the three dimensional distribution.

Dust concentrations aloft were all very low ($< 20\ \mu g/m^3$). Some photographs illustrating the sharpness of the smog front and the differences in visibility across it are shown in Figures 26, 27, and 28.

Figure 25. Low level haze layer observed toward the southeast of a point east of Palmdale at an elevation of 3300' at 0935 PST, 17 Oct. 1977.

Figure 26. Smog over San Bernardino Mountains at 5000', looking northeastward at 1447 PST, 17 Oct, 1977. (Compare with Figure 27.)

Figure 27. Palm Springs, looking north toward Little San Bernardino Mountains, at 1520 PST, 17 Oct. 1977. (Compare with Figure 26.)

(v) 18 October 1977

On this day the northern and eastern portions of the desert were investigated (Figure 31). On the morning of the 18th, the trough at 500-mb was well-defined off the west coast (Figure 28) while at the surface a front was approaching the Washington coast. The thermal trough had changed little during the previous day, although the pressure gradient on its east side was somewhat weaker. The decreased easterly flow favored continued deepening of the marine layer over the Los Angeles Basin.

As illustrated by the surface winds shown in Figure 29 the flow in the desert north of the Los Angeles Basin was generally from the southwest. In the southern and eastern ends of the desert the flow is from the southeast, except in the vicinity of the Salton Sea which is definitely under the influence of a sea breeze. The smog front shown was quite diffuse and difficult to locate. Only the single point along route I-10 was identified from the aircraft. There was considerable reduction of visibility over much of the desert well east of the "front", as can be seen from the photograph of Figure 33.

Temperature soundings made on the 18th (Figure 30) showed increased maximum mixing depth everywhere. Thus, San Diego's marine layer deepened by about 700' to 2000' and all of the desert stations' mixing depths exceeded 5000'.

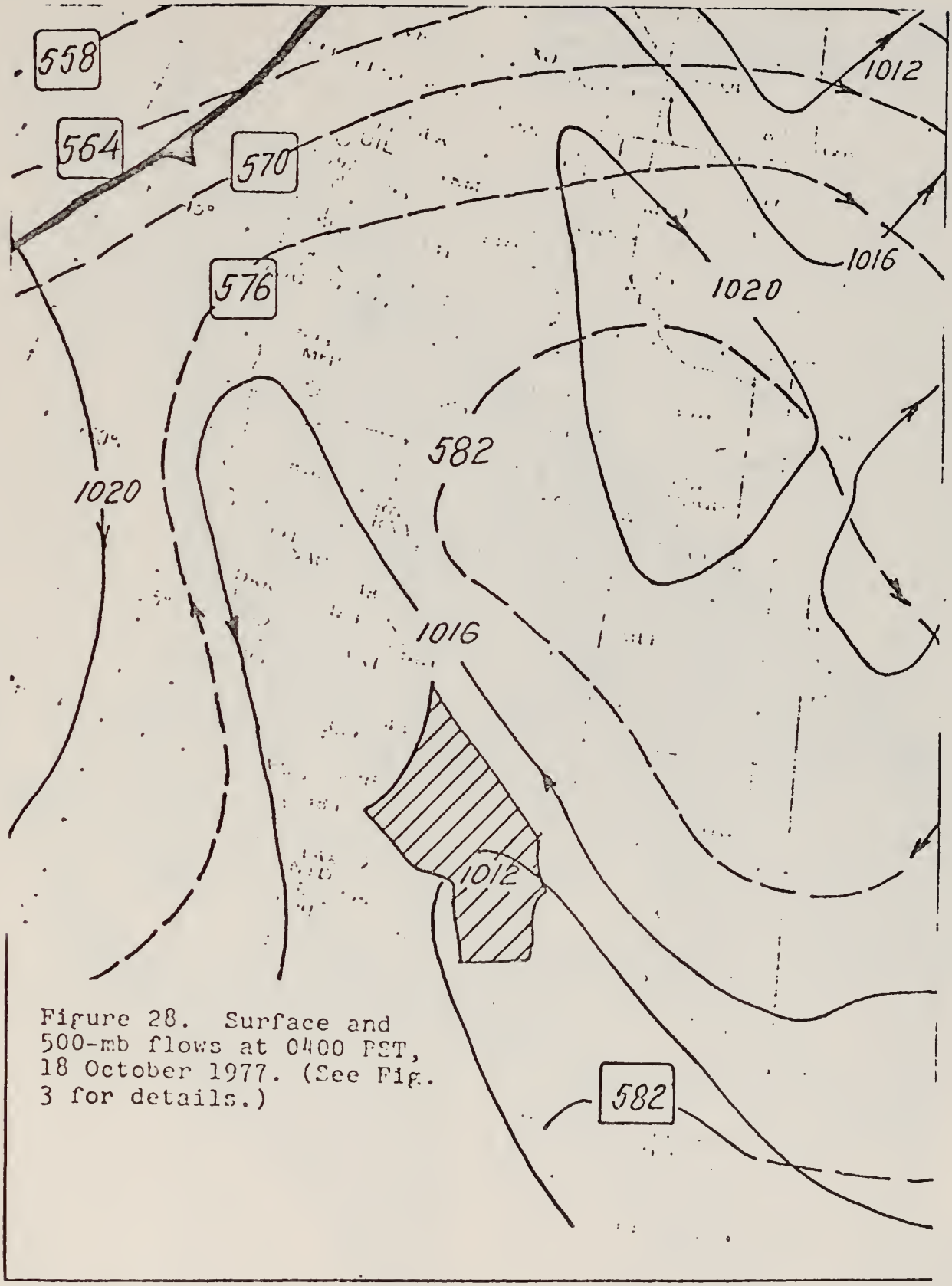


Figure 28. Surface and 500-mb flows at 0400 PST, 18 October 1977. (See Fig. 3 for details.)

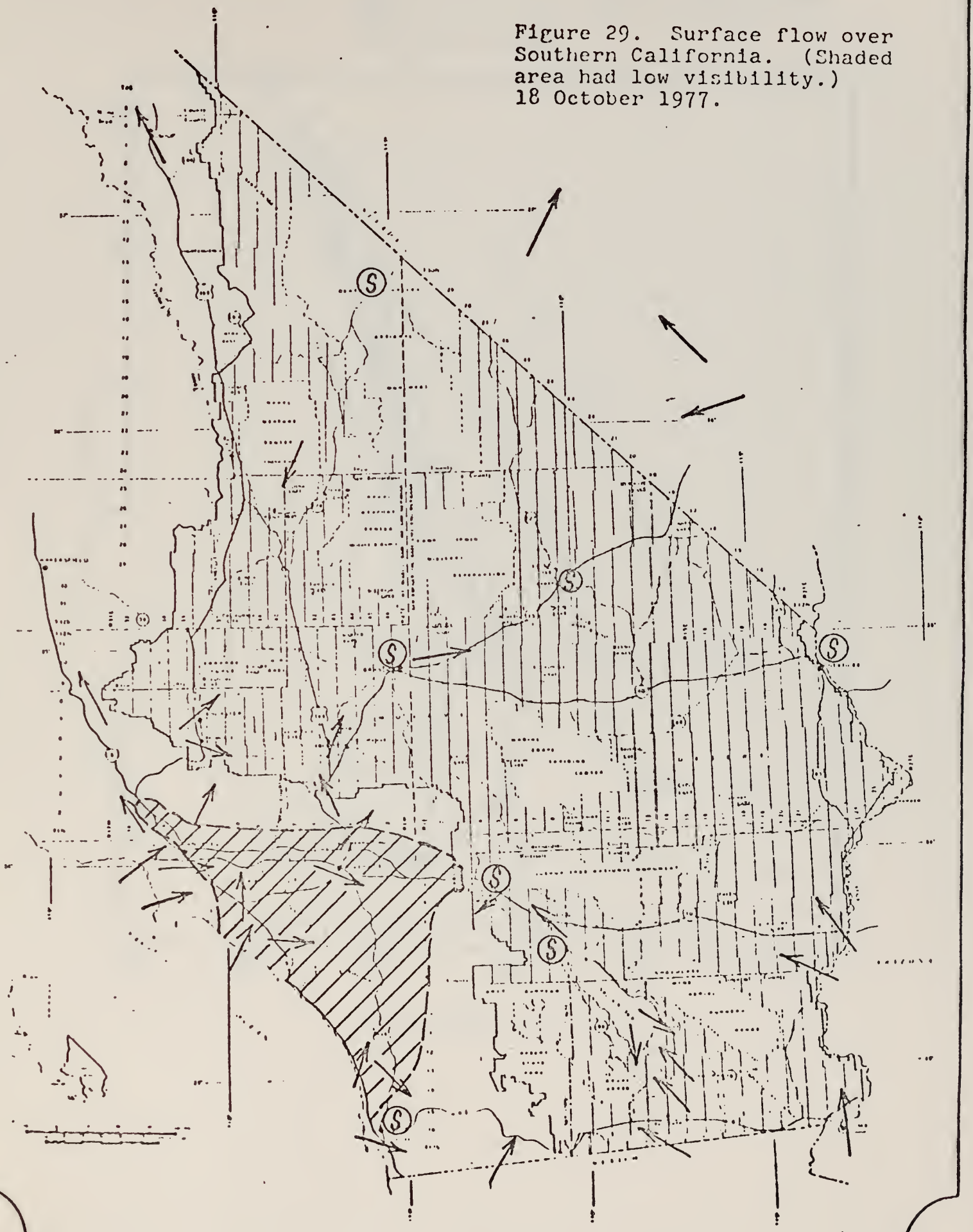
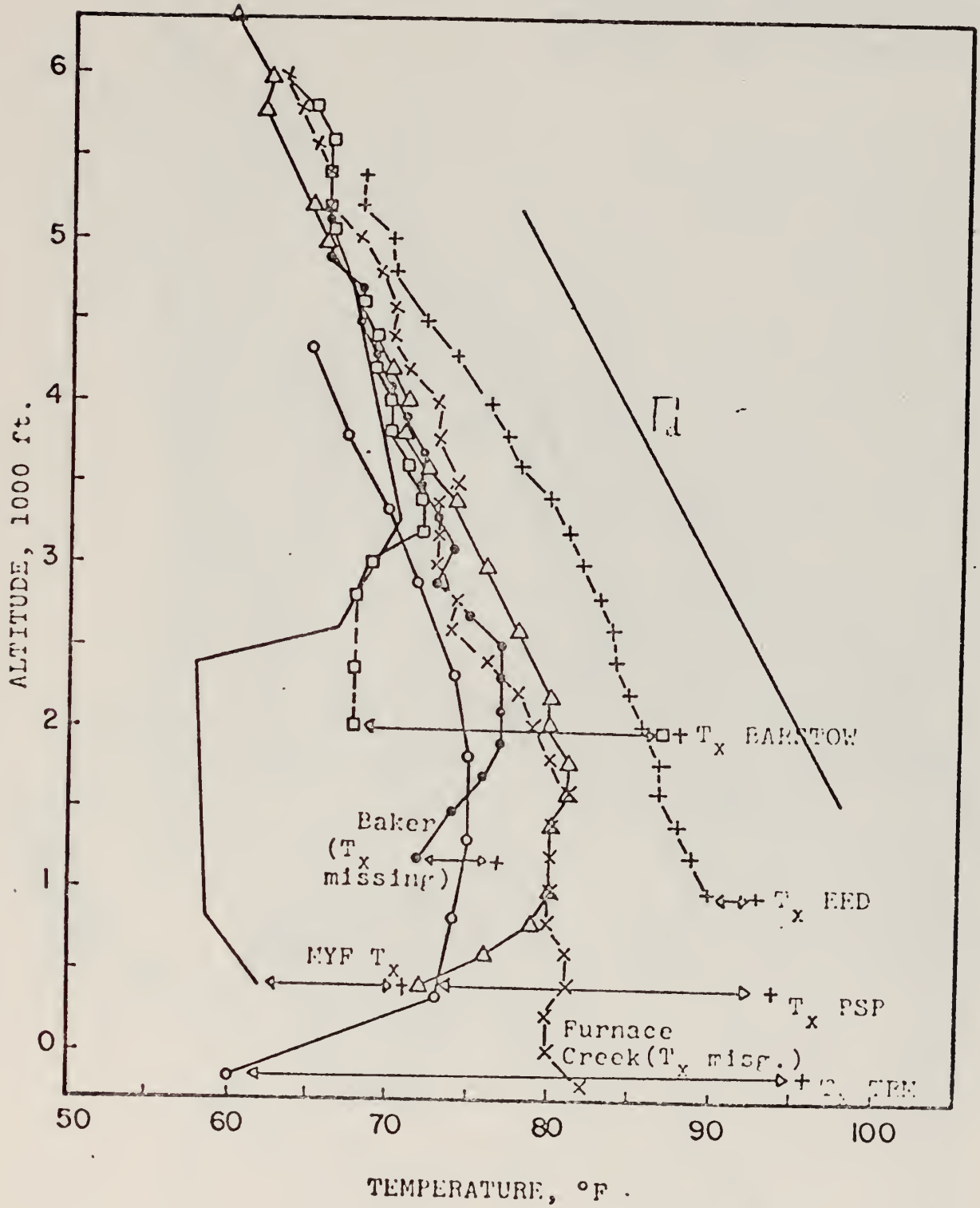


Figure 29. Surface flow over Southern California. (Shaded area had low visibility.) 18 October 1977.

Figure 30. Temperature soundings at San Diego (MYF, 0400 PST), Thermal (TRM, 0900 PST), Palm Springs (PSP, 0727 PST), Barstow (0822 PST), Baker (0907 PST), Furnace Creek (0954 PST), and Needles (EED, 1454 PST), on 18 October 1977.



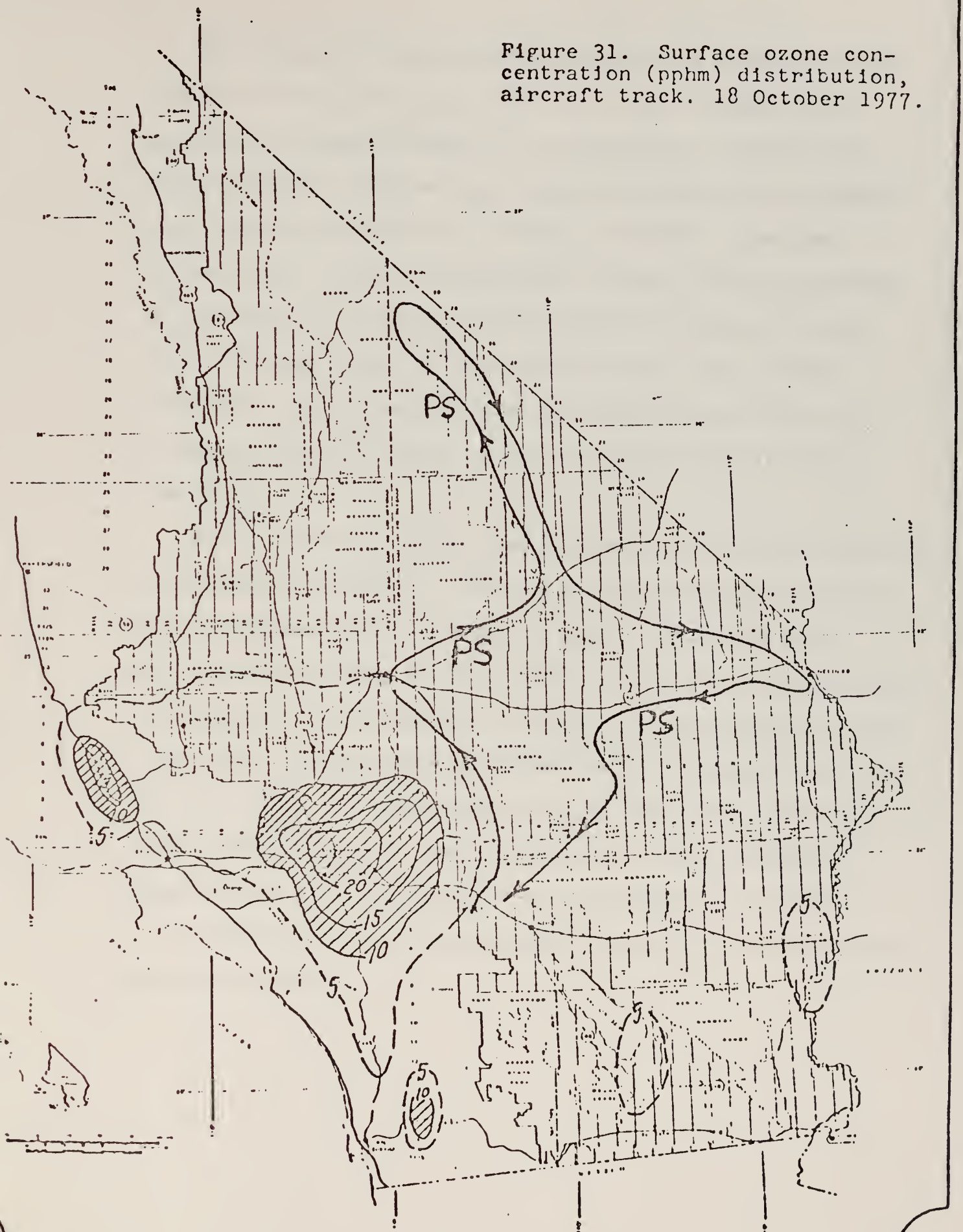


Figure 31. Surface ozone concentration (pphm) distribution, aircraft track. 18 October 1977.

The distribution of ozone concentration at the surface was much like that of the previous day, except high values extended farther eastward and northward (Figure 32) into the desert. Around midday a peak of 10 pphm was observed near Imperial and Victorville recorded a maximum hourly concentration of 30 pphm at 1800 PST. Some other observed hourly maxima: San Bernardino, 24 pphm (1500 PST); Redlands, 24 pphm (1600 PST); Yucaipa, 19 pphm (1700 PST); Banning, 15 pphm (1900 PST); Palm Springs, 17 pphm (2000 PST); and Indio, 13 pphm (2100 PST). Clearly there had been significant transport from the Los Angeles Basin and perhaps, in the case of the Imperial Valley, from Mexico.

Aircraft soundings of ozone and temperature and wet-bulb temperature are presented in Figure 33. The ozone at Palm Springs (early morning sounding) extended over a considerable depth. Most of the other morning soundings showed relatively low concentration. In Death Valley, at Furnace Creek, the concentration was low (< 4 pphm) except in stable layers aloft (300-500' above the ground) where the concentration reached 10 pphm. (There were brief periods when the level increased to much more than 10 pphm but there is some uncertainty as to their validity.) However, there is little doubt that intense laminae do exist aloft.

Particulate samples showed extremely low levels of air-borne dust - less than 20 $\mu g/m^3$.

Figure 32a. Sounding of dry- and wet-bulb temperatures and ozone at Palm Springs (0727-0744 PST, 18 Oct.)

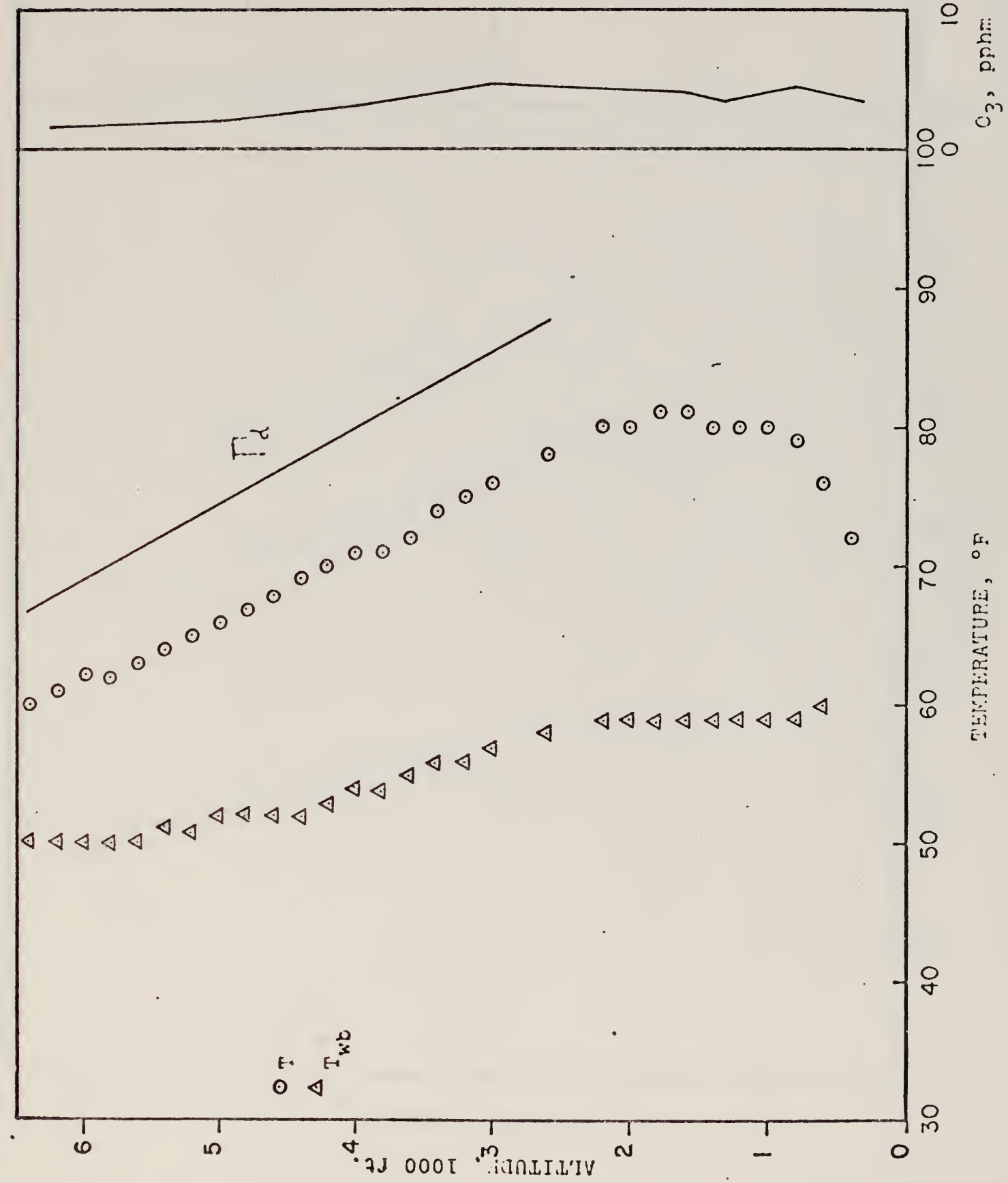


Figure 32b. Sounding of dry- and wet-bulb temperatures and ozone at Barstow (0822-0834 PST, 18 October 1977)

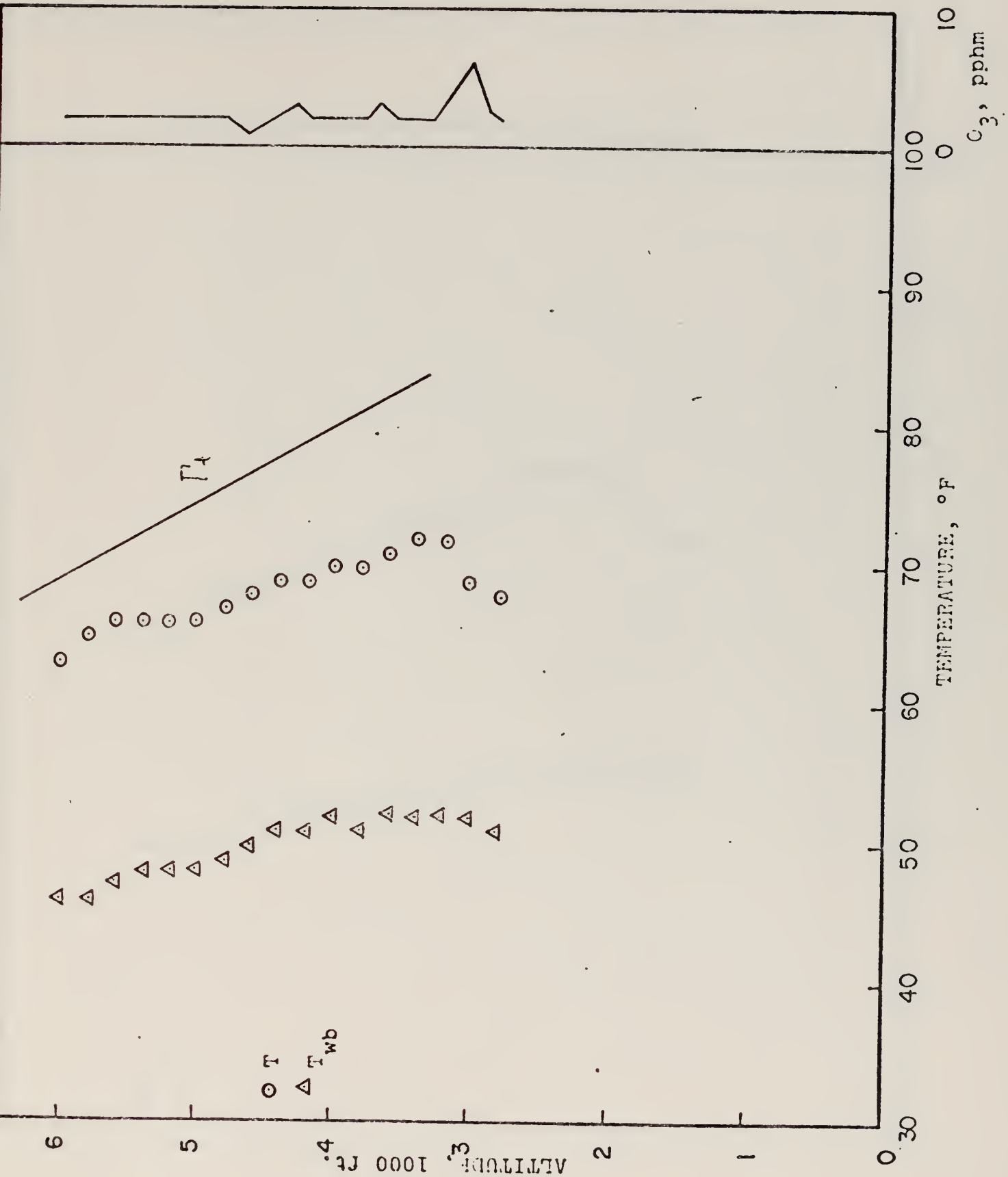


Figure 32c. Sounding of dry- and wet-bulb temperatures and ozone at Baker (0907-0917 PST, 18 October 1977.)

Figure 32d. Sounding of dry- and wet-bulb temperatures and ozone at Furnace Creek (0954-1016 PST, 18 Oct. 1977)

Figure 32c. Sounding of dry- and wet-bulb temperatures and ozone at Needles (1454-1521 PST, 18 October 1977.)

Figure 33. Coachella Valley seen from Palm Springs looking southeastward at an altitude of 6000' at 0743 PST, 18 Oct. 1977.

(vi) 19 October 1977

The flight track covered the southern portion of the study area (Palm Springs/Thermal/Blythe/Imperial), and then returned to San Jose from Palm Springs. The 500-mb trough off the California coast had deepened and moved inland, leading to increased southerly wind and decreased stability. The thermal trough at the surface had deepened and moved eastward slightly.

Westerly winds had strengthened along the coast and migrated inland (Figure 34). There was not much sign of a smog front anywhere. Visibilities were generally excellent along the coast, somewhat poor over the interior valleys of the Los Angeles Basin and definitely less than normal (10-15 miles) over the western desert. In the Coachella Valley, several layers of haze could be discerned.

The depth of maximum mixing continued to increase over San Diego (3400') but decreased over the Coachella and Imperial Valleys (at Thermal, to 1500' and at Imperial to 2500'). There had been cooling at low levels over the desert (Figure 35).

Again, particulate loading was extremely low everywhere in the desert (generally less than 20 $\mu g/m^3$). On the morning soundings (Figure 36), the ozone was relatively low (< 3 pphm), except over Thermal. There was still some low-level breeze as illustrated by Figure 37.

Figure 34. Surface winds, 1300 PST, 19 October 1977. The shaded areas are zones of diminished visibility.

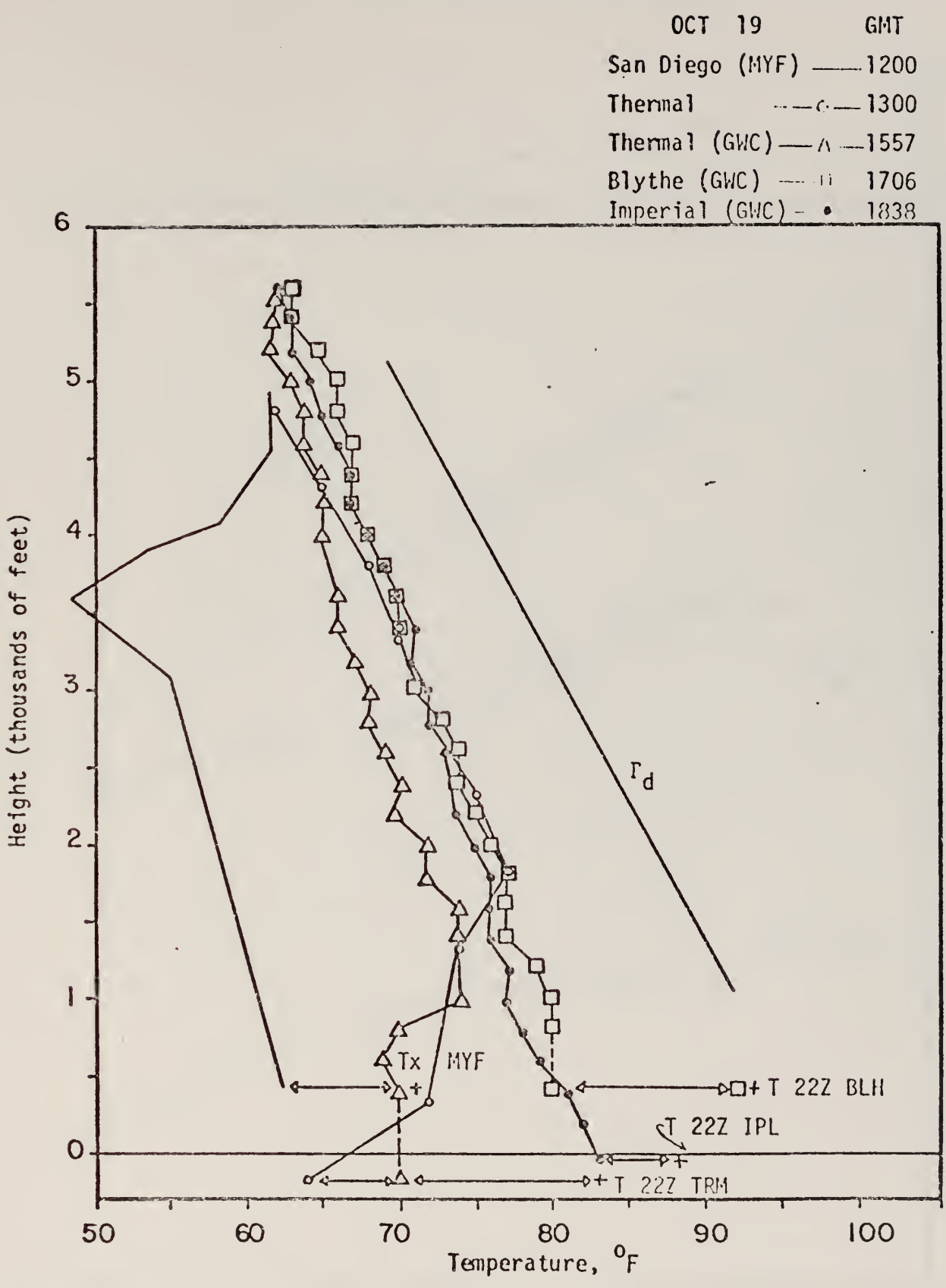


Figure 35. Temperature soundings at San Diego (MYF, 0400 PST), Thermal (TRM, 0400 PST, and 0757 PST), Blythe (BLH, 0906 PST) and Imperial (IPL, 1038 PST) on 19 October 1977.

Figure 36a. Temperature and wet-bulb and ozone soundings at Thermal (0757-0810 PST, 19 October 1977).

Figure 36b. Temperature, wet-bulb, and ozone soundings at Blythe (0906-0918 PST, 19 October 1977).

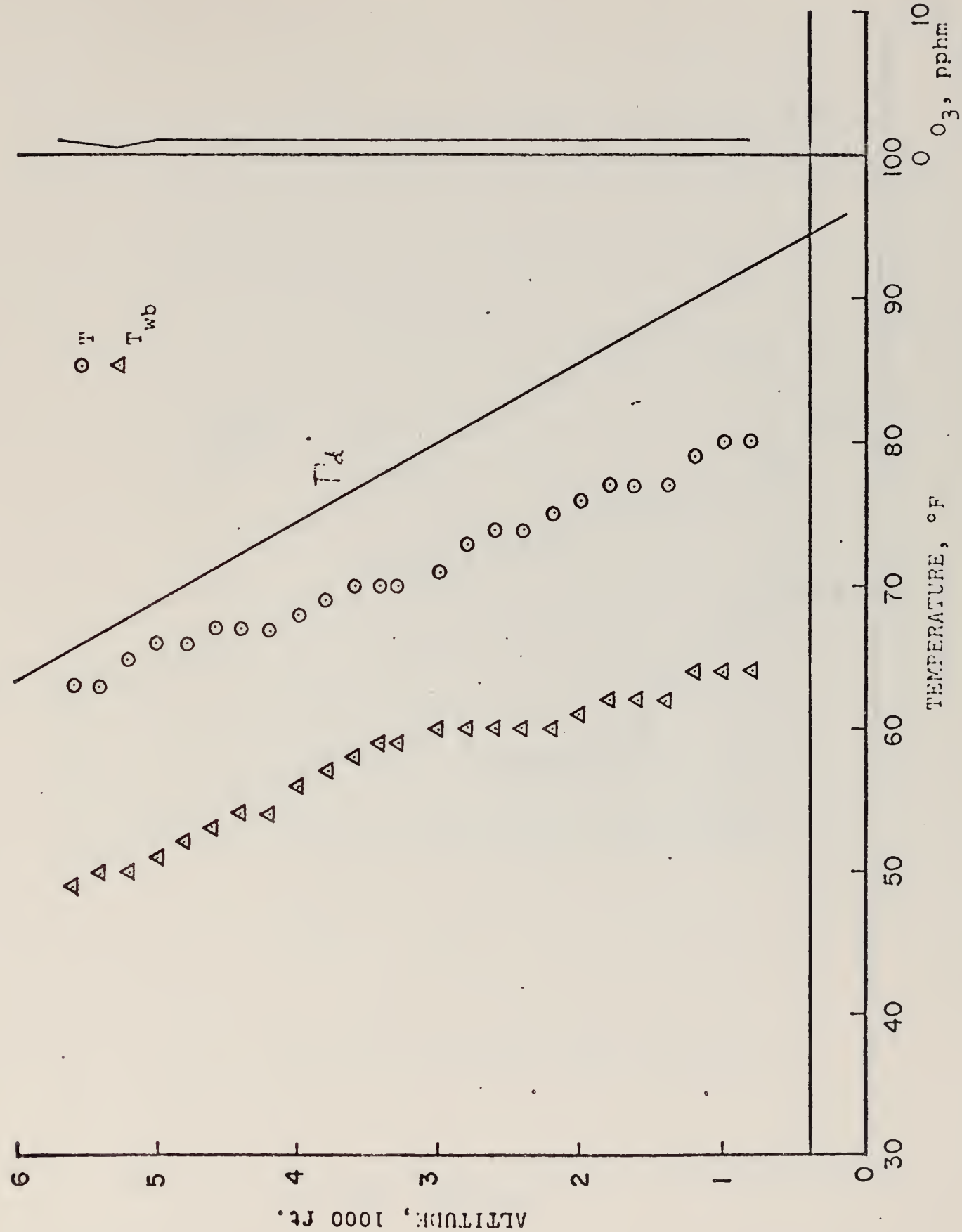


Figure 36c. Temperature, wet-bulb, and ozone soundings at Imperial (1038-1050 PST, 19 October 1977).

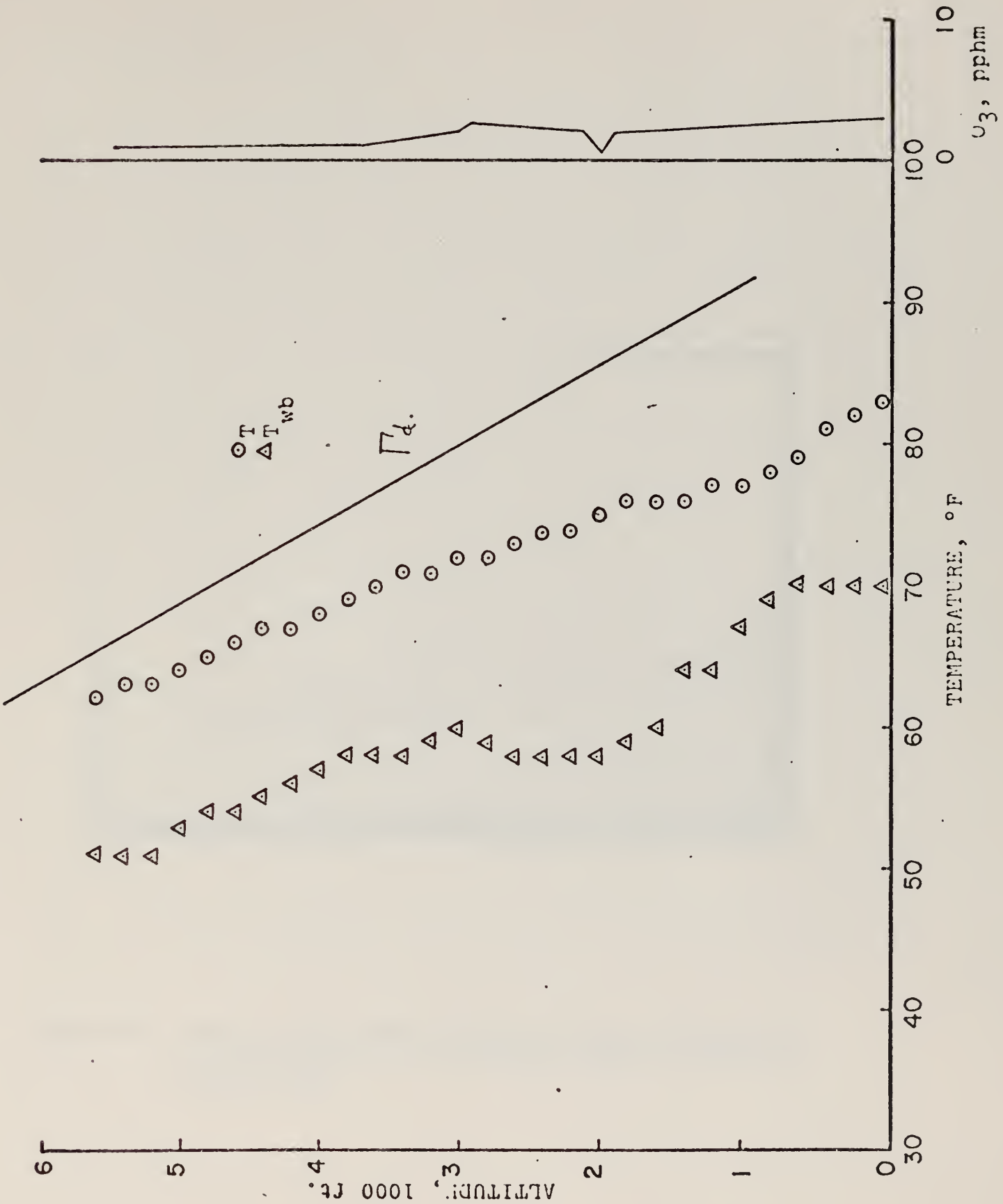


Figure 37. Low-level haze looking southward from a point just SE of Palm Springs, at an altitude of 1000' at 0749 PST, 19 Oct. 1977.

3. Conclusions and Recommendations

At the outset of the period of observations, the maximum inland penetration of oxidants and particulates from the coastal belt was near the San Gabriel, San Bernardino, San Jacinto, and Vallecito Mountains. On the desert side of this smog front, oxidant levels were low (< 3 pphm) and so were particulates (< 20 $\mu g/m^3$). The flow on the desert side of this quasi-stationary front was easterly (NNE to SE) while on the coast side it was weak westerly. The marine air was shallow (< 1000 feet at San Diego) while the depth of the mixing layer in the desert air was great (> 5000').

Near the middle of the period, the prevailing flow changed with the easterlies weakening significantly and the onshore flow in the marine air increased from the southwest. The depth of the marine air increased markedly and the polluted coastal air crossed the mountain barriers into the desert. Although the concentrations of particulates over the desert did not increase, the levels of oxidants increased everywhere. There is some indication that as the gaseous pollutants push across the coastal mountains, they often move out over the desert in elevated laminae. These laminae may then be periodically "tapped" by convection, bringing high levels of oxidants to the surface. Thus, the high ozone concentration sometimes observed in remote areas (e.g., over Death Valley) may be due to a down flux from ozone-rich layers.

Although the results of this brief investigation are not conclusive, certain aspects of the air flow and its effect on pollution over the Californian desert did evolve. Under synoptic conditions of the type discussed here, it is suggested that (1) there is no substantial transport of particulates over great distances in the desert, and (2) gaseous pollutants (e.g., oxidants and their precursors) spread over the desert, far from their source regions in elevated stable layers. (Mexico may often be an important source for the Imperial Valley.)

Much more work needs to be done to define both the background levels over the desert and transport from adjacent populated areas. Many more permanent observation sites are needed in the central desert (e.g., at 29 Palms, Baker, Amboy, and Death Valley) in order to establish statistically the background levels and influxes. In order to find the elevated laminae and determine vertical transport, regular temperature and ozone soundings should be made to at least 10,000 ft. over many parts of the desert. In this regard, air trajectories should be determined, perhaps by tracking constant density balloons. Systematic surveys by aircraft, such as the one reported on herein, should be repeated under a variety of atmospheric flows during the Spring and Summer as well as the Fall. Particular attention should be given to those flow patterns (such as a low off the California coast) that enhance the transport into the desert and may lead to locally-high concentrations of pollutants, such as the sea and land breezes in the vicinity of the Salton Sea.

4. Acknowledgments

Many persons contributed substantially to the efforts described herein. First of all, Mr. Dudley Smith, meteorologist of BLM at Riverside, helped enormously in the initial planning of the flights, in providing potential sources of supporting meteorological and air pollution data, and in being a rich source of reference material on the desert.

Data were made available to this program by Dr. Paul Phelps of the Lawrence Livermore Laboratories, Edwards Air Force Base, H.A. Marmon, Jr., U.S. Army, Yuma Met. Support Team and the Air Resources Board personnel at the El Monte and Sacramento offices. We gratefully acknowledge the use of these data and the efforts by individuals to transmit them to GWC in such a short time. Data reduction was accomplished by L. Lanham and S. Kolstad.

Finally, we would like to acknowledge Richard Nederostek, aircraft pilot for the observation period, and Richard Simon, on-board observer during the flights.

Appendix 1. Data Sources.

The following data, on which this report is based, are on file in GWC's offices.

A. Aircraft

1. Flight plan and maps, descriptions of flight problems and observations.
2. Flight logs.
3. Ozone strip charts and tabulated values at regular intervals.
4. CO and particulate concentrations, tabulated.

B. Supporting Weather Data

1. Facsimile maps for entire period.
2. All hourly surface reports (airways) and rawinsondes in the area during the entire period.
3. Air Resources Board data, including:
   (a) Special pibals
   (b) APOBS (Riverside and Thermal)
   (c) Air Quality observations (O_3, CO, NO_x), from
      (1) ARB Van near Blythe (1 station)
      (2) Imperial Valley APCD (1 station)
      (3) San Diego County APCD (3 stations)
      (4) S. California APCD (Azusa not plotted) (24 stations)
      (5) South Coast Air Quality Management District, total particulates (16 stations)

4. Supporting soundings at
   (a) Yuma
   (b) Edwards AFB
5. Lawrence-Livermore Labs air quality and surface observations (6 stations)
6. Crestline air quality and surface observations (1 station)

SUMMARY OF PARTICULATE SAMPLES

Sample No.	Date	Time (PDT)	Duration (min)	Location	Altitude MSL (ft)	Net Volume (m-3)	Weight Change (mg)
1	14	1757-1807	10	San Bernardino to Beaumont	5500	44	0[1]
2	15	1601-1611	10	SW corner, Salton Sea	100	44	X[2]
3	15	1745-1755	10	Hemet	2200	44	0
4	16	0939-0953, 1000-1005	19	Motorcycle Race SE of Plaster City	500 (100'AGL)	84	+30.7
5	17	1232-1247	15	Koehn Dry Lake	3300	66	0
6	17	1513-1525	12	Lland to Cajon Pass	4600	53	0
7	18	0947-1002	15	Midway between Barstow and Baker	1600-2000 (200-600 AGL)	66	0
8	18	1318-1333	15	Over Death Valley South of Furnace Creek	0 (200'AGL)	66	X[2]
9	18	1710-1725	15	Essex to Chambless	200'AGL	66	0
10	19	0948-1003	15	30 to 10 miles West of Blythe	200'AGL	66	0
11	19	1213-1227	14	West of Thermal	400 (500'AGL)	62	0

[1]Zero indicates weight change was less than 1 mg.

[2]Damaged filter.

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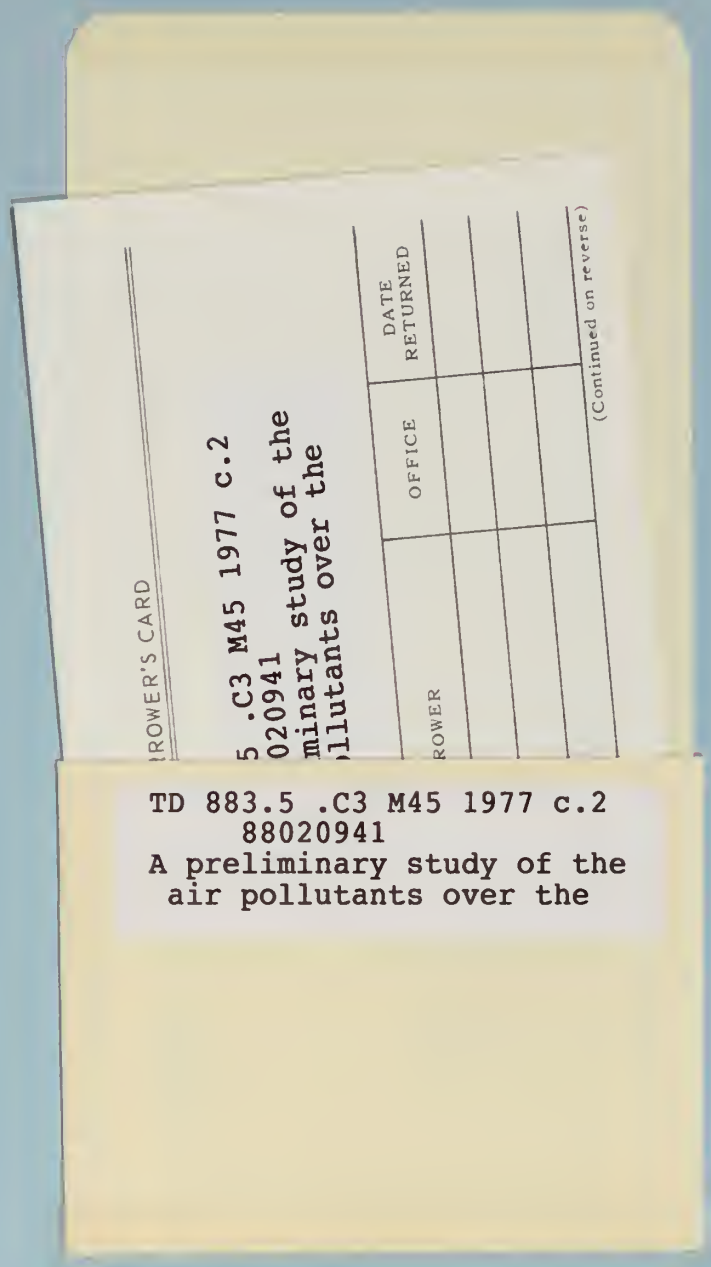

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air pollutants over the